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Special acknowledgment is due Ms. Najoua Ksontini, PH, former SEWRPC Senior Engineer and Mr. Michael G. Hahn, PE, PH, SEWRPC Principal Engineer for their contributions to the preparation of this report.

MEMORANDUM REPORT NUMBER 141

ANALYSIS OF ALTERNATIVE PLANS FOR REMOVAL OF THE CONCRETE LINING IN UNDERWOOD CREEK IN THE CITY OF WAUWATOSA

MILWAUKEE COUNTY, WISCONSIN

Prepared by the

Southeastern Wisconsin Regional Planning Commission

for the

Milwaukee Metropolitan Sewerage District

November 2000

Inside Region\$10.00Outside Region\$20.00

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INTRODUCTION AND BACKGROUND

In March of 1999, the Milwaukee Metropolitan Sewerage District (MMSD) requested that the Southeastern Wisconsin Regional Planning Commission (SEWRPC) perform hydrologic and hydraulic analyses and evaluate alternative floodland management plans for the Underwood Creek subwatershed of the Menomonee River watershed. The analyses are primarily intended to evaluate alternative plans to enable removal of the existing concrete lining and enhance the available storage in that portion of the Creek that flows through the City of Wauwatosa in Milwaukee County.

The SEWRPC staff has recently completed a stormwater and floodland management system plan for the Underwood Creek and Dousman Ditch subwatersheds in the City of Brookfield and the Village of Elm Grove, upstream of the Milwaukee County portion of the Creek.¹ One aspect of that system plan is the evaluation of certain floodland management alternatives designed to alleviate flooding problems in Brookfield and Elm Grove. All of the alternative plans and the recommended plan developed under that study are designed to avoid increasing flood flows and stages in Wauwatosa. The study presented herein evaluates alternative plans in the context of the recommended floodland management plan for Brookfield and Elm Grove.

The following tasks were performed under this study as requested by the District:

- Determination of Underwood Creek flood flows and profiles under existing channel conditions
- Determination of Underwood Creek flood flows and profiles assuming implementation of alternative measures upstream of the Milwaukee-Waukesha county line
- Review of preliminary analyses developed by MMSD assuming removal of the existing concrete lining in the Wauwatosa reach of Underwood Creek
- Field survey to collect data at three hydraulic structures along the study reach
- Analysis of the feasibility of implementing measures to maintain or reduce the planned land use, planned channel 100-year flood flows and profiles along Underwood Creek with the concrete channel lining removed in Milwaukee County

DESCRIPTION OF STUDY AREA

As shown on Map 1, the 19.9-square-mile Underwood Creek subwatershed includes portions of the Cities of Brookfield, Milwaukee, New Berlin, Wauwatosa, and West Allis, the Village of Elm Grove, and the Town of Brookfield. The three main streams within the subwatershed are: 1) Underwood Creek, which has its source in a large wetland located north of the Canadian Pacific Railway in the northwestern part of the subwatershed in the City of Brookfield; 2) Dousman Ditch, which has its source at the Wisconsin Avenue storm sewer outfall north of W. Bluemound Road in the west central part of the subwatershed in the City of Brookfield; and 3) the South Branch of Underwood Creek, which has its source at the outfall of an 0.65-mile-long enclosure that is located between W. Greenfield Avenue and Theodore Trecker Way extended in the southeastern part of the subwatershed

¹SEWRPC Community Assistance Planning Report No. 236 (CAPR No. 236), A Stormwater and Floodland Management System Plan for the Dousman Ditch and Underwood Creek Subwatersheds in the City of Brookfield and the Village of Elm Grove, Waukesha County, Wisconsin, February 2000.

Map 1



THE UNDERWOOD CREEK SUBWATERSHED

LEGEND

SUBWATERSHED BOUNDARY
PERENNIAL STREAM REACH



2

Source: SEWRPC.

in the City of West Allis. Approximately 3.5 square miles are tributary to Dousman Ditch, 5.2 square miles are tributary to the South Branch of Underwood Creek, and the remaining 11.2 square miles are directly tributary to Underwood Creek.

This study considered the effects of runoff from the entire 19.9-square-mile subwatershed, but the hydraulic analysis focused on the 2.5-mile-long reach of Underwood Creek from its confluence with the South Branch, just downstream of the Milwaukee-Waukesha county line, to its confluence with the Menomonee River.

HYDROLOGIC AND HYDRAULIC ANALYSIS METHODS

The base model for the hydrologic analyses was the U.S. Environmental Protection Agency HSPF continuous simulation model developed by the SEWRPC staff under the Underwood Creek/Dousman Ditch (UC/DD) stormwater and floodland management plan and modified by the District's engineering consultant, Camp Dresser & McKee, Inc. (CDM), under the MMSD Menomonee River watershed watercourse system plan. Additional modifications to the flow routing portion of that model were made by SEWRPC staff for the study described herein. Those modifications were related to the reconfiguration of the Underwood Creek and South Branch of Underwood Creek channel and/or overbanks to accommodate the proposed removal of the concrete lining in Underwood Creek.

The hydraulic analyses were performed using the U.S. Army Corps of Engineers HEC-RAS Version 2.2 River Analysis Systems model developed for Underwood Creek and the South Branch of Underwood Creek by the SEWRPC staff. That model is an updated version of the U.S. Army Corps of Engineers HEC-2 water surface profiles model developed by the SEWRPC staff under the 1976 Menomonee River watershed study,² refined by the SEWRPC staff under the 1990 stormwater drainage and flood control system plan for the MMSD,³ and again refined under the Underwood Creek/Dousman Ditch stormwater management plan (SEWRPC CAPR No. 236).

CRITERIA FOR THE EVALUATION OF ALTERNATIVE FLOODLAND MANAGEMENT PLANS

The floodland management alternatives related to removal of the concrete channel lining along the Milwaukee County reach of Underwood Creek were developed within the context of the floodland management goals, objectives, standards, and criteria that were established by an interagency committee under the MMSD Menomonee River watershed watercourse system planning effort. That committee included members of the staffs of the District, Milwaukee County, the Wisconsin Department of Natural Resources, and the Regional Planning Commission. The goals, objectives, standards, and criteria are set forth in Appendix A of this report.

Flood flows and stages were computed for a range of floods with recurrence intervals between two and 100 years; however, emphasis is placed on the 100-year flood since that event is the regulatory flood for zoning purposes and the commonly accepted standard for flood control planning.⁴

Several alternative plans for removal of the concrete channel lining in Underwood Creek were investigated under this study. The most significant criterion used to evaluate each alternative plan was whether implementation would increase the potential flood hazard along Underwood Creek during the 100-year flood.

²SEWRPC Planning Report No. 26, A Comprehensive Plan for the Menomonee River Watershed, October 1976.

³SEWRPC Community Assistance Planning Report No. 152, A Stormwater Drainage and Flood Control System Plan for the Milwaukee Metropolitan Sewerage District, December 1990.

⁴*The 100-year recurrence interval flood has a 1 percent probability of occurrence in any year.*

3

DETERMINATION OF FLOOD FLOWS AND PROFILES UNDER EXISTING CHANNEL CONDITIONS

Flood flows and profiles along the Milwaukee County portion of Underwood Creek were determined for floods with recurrence intervals of two, 10, 50, and 100 years under both existing 1995 and planned year 2020 land use and existing channel conditions. The flood flows and profiles that were developed for the July 28, 1999 preliminary draft of this report were subsequently refined during the analysis of three additional alternative plans (Alternative Plans EE, EP, and FP). Those refinements resulted from changes to the flood routing component of the hydrologic model to represent floodwater storage sites in greater detail. The refinements resulted in relatively minor changes in estimated flood flows and stages under existing and planned use conditions with existing channel conditions. The original flood flows and stages, which are set forth in Appendix B, are adequate for evaluation of the relative impacts of the three original alternative plans that are designated Alternatives A, B, and C. The final flood flows and stages under existing (1995) land use and existing channel conditions and planned 2020 land use and existing channel conditions are set forth in Tables 1 through 3. Existing channel flood profiles are set forth in Figures 1 and 2.

Because land use in the subwatershed is close to buildout conditions, the flood flows and stages for 1995 and 2020 land use conditions are not greatly different.

The analysis considers the interaction between the main stream channel and the old channel that flows approximately parallel to the existing channel between N. 111th Street extended and N. 121st Street extended.⁵ Dimensions and elevations of the three hydraulic structures along the old channel were surveyed by the SEWRPC staff as part of this study. Those structures are shown on Map 2. Overflow from the main stream to the old channel occurs when flood stages in the main stream exceed the invert elevations of the two 42-inch-diameter corrugated metal pipe (CMP) culverts under the Canadian Pacific railway near N. 121st Street extended. The overflow from the main channel into the old channel then flows to the northeast through a 54-inch-diameter reinforced concrete pipe (RCP) culvert under N. 115th Street and finally returns to the main channel through two 72-inch-diameter RCP culvert pipes under the railway near N. 111th Street extended. The two CMP culverts at the upstream end restrict the inflow to the old channel to a greater degree than the clear span bridge that was previously located under the railway, but they do enable the old channel to serve as a storage/conveyance feature that helps to limit flood stages along the main channel.

DETERMINATION OF FLOOD FLOWS AND PROFILES ASSUMING IMPLEMENTATION OF RECOMMENDED PLAN MEASURES UPSTREAM OF THE MILWAUKEE-WAUKESHA COUNTY LINE

The effect on 100-year recurrence interval flood flows and the 100-year profile along the Milwaukee County portion of Underwood Creek under planned year 2020 land use conditions was considered for recommended plan conditions as set forth in the Underwood Creek/Dousman Ditch stormwater and floodland management plan. The recommended plan calls for construction of an overflow channel/box culvert in the Village of Elm Grove along with the provision of on-line compensating floodwater storage to avoid increases in downstream two- through 500-year flood stages in the City of Wauwatosa. In subsequent sections of this memorandum, the alternative plans developed for removal of the concrete lining in Underwood Creek are evaluated assuming implementation of the recommended plan for Brookfield and Elm Grove.

⁵The land along the old channel is not currently designated as 100-year floodplain under the December 1978 Federal flood insurance study for the City of Wauwatosa or under the City zoning ordinance. However, it would be appropriate to apply such a designation since there is a hydraulic connection with the Underwood Creek floodplain at both the upstream and downstream ends of the old channel. Designation of a floodplain along the old channel will be recommended by the Regional Planning Commission under future work programs.

Table 1

UNDERWOOD CREEK FINAL FLOOD FLOWS-EXISTING CHANNEL WITH EXISTING (1995) AND PLANNED (2020) LAND USE CONDITIONS

					Boourroom				
		.							
		Iwo	-Year	10-Year		50-Year		100-Year	
Location (River Mile)	Description	1995 Land Use (cfs)	2020 Land Use (cfs)						
0.00	Confluence with Menomonee River	2,590	2,650	4,800	4,880	6,630	6,710	7,360	7,430
0.76	Upstream side of USH 45	2,550	2,610	4,710	4,790	6,470	6,550	7,180	7,250
1.26	About 590 feet down- stream of Mayfair Road	2,240	2,280	4,050	4,110	5,490	5,550	6,050	6,120
1.53	Upstream side of W. Watertown Plank Road	2,020	2,070	3,630	3,700	4,890	4,960	5,380	5,450
1.62 ^a	Just upstream of location where flow from old channel returns to Underwood Creek	2,020	2,070	3,490	3,560	4,730	4,800	5,190	5,260
2.21 ^a	Just upstream of location where some flow in Underwood Creek is diverted to old channel	2,020	2,070	3,630	3,700	4,890	4,960	5,380	5,450
2.5	Just downstream from confluence with the South Branch of Underwood Creek	1,710	1,760	3,050	3,140	4,090	4,180	4,490	4,580

^aBetween River Miles 1.62 and 2.21, some flow leaves the main stem of Underwood Creek and enters the old stream channel. The flows at those river mile locations reflect that diversion.

Source: SEWRPC.

ANALYSIS OF ALTERNATIVE PLANS TO REMOVE THE CONCRETE LINING FROM UNDERWOOD CREEK IN MILWAUKEE COUNTY

Study Criteria

The SEWRPC staff developed and evaluated measures designed to remove the concrete lining from Underwood Creek in Milwaukee County while avoiding increases in the 100-year flood profile relative to planned land use and existing channel conditions, where possible. Attempts to avoid increases in the 100-year flood stage focused on increasing the hydraulic capacity and/or the available floodwater storage volume along the Milwaukee County portion of the Creek.

It was assumed that the eight existing weir/grade control structures would be replaced with more natural structures that would be modified to permit fish migration. The analyses described in this memorandum apply hydraulic properties characteristic of a rehabilitated natural stream which would include pool, riffle, and run sequences in a meandering low flow channel; substrate enhancement; and bank vegetation consisting of grasses that would minimize resistance to flow while providing shade for the low flow channel. If the channel rehabilitation project is selected to be implemented, it is assumed that MMSD would develop specific rehabilitation measures during the detailed design phase of the project.

Table 2

UNDERWOOD CREEK FINAL FLOOD STAGES: EXISTING CHANNEL WITH EXISTING 1995 LAND USE CONDITIONS

Location		Flood Stage Elevation (feet above NGVD 1929)			
(River Mile)	Description	Two-Year	10-Year	50-Year	100-Year
0.06		672.68	675.30	676.74	677.25
0.11		672.96	675.57	676.99	677.48
0.22		673.65	676.31	677.79	678.28
0.225		675.42	677.41	678.71	679.20
0.23		675.79	678.10	679.63	680.21
0.33		677.78	680.32	682.37	682.94
0.42		678.38	680.94	682.92	683.44
0.468		679.13	681.96	684.00	684.64
0.475		679.43	682.37	684.46	685.14
0.49		679.69	682.71	684.80	685.48
0.491		679.59	682.63	684.73	685.42
0.495		679.55	682.62	684.75	685.45
0.52		679.70	682.73	684.83	685.52
0.63		680.08	682.91	684.91	685.57
0.635		680.03	681.76	683.90	684.57
0.67	· · · · · ·	680.90	683.25	684.89	685.57
0.675		684.23	685.95	687.30	687.76
0.72		685.62	687.86	689.33	689.83
0.725		685.63	687.86	689.32	689.82
0.73		685.03	687.28	688.78	689.28
0.74	Downstream USH 45	686.02	688.64	690.29	690.88
0.76	Upstream USH 45	686.16	688.76	690.39	690.97
0.8		686.94	689.84	691.66	692.32
0.805		689.48	691.35	692.76	693.25
0.81		690.70	692.90	694.41	694.73
0.8125	Canadian Pacific Railway (bridge)			:	'
0.815		691.83	694.89	698.23	701.51
0.82		692.77	695.85	699.03	701.66
0.83		692.83	695.93	699.12	701.72
0.94	. –	692.77	695.81	699.06	701.68
1.04		693.06	695.74	698.92	701.58
1.14		693.78	696.21	699.18	701.74
1.26		694.76	696.56	698.96	701.49
1.27	Downstream Mayfair Road	695.96	698.38	700.31	702.28
1.275	Upstream Mayfair Road	695.98	698.40	700.32	702.28
1.28		695.23	697.64	699.73	701.93
1.37		696.93	699.07	700.64	702.28
1.45		697.27	699.44	700.97	702.44
1.46		698.57	700.53	701.78	702.21
1.461	Union Pacific Railroad	699.63	701.94	703.53	704.13
1.462		699.91	702.24	703.86	704.43
1.47		701.68	705.26	707.70	708.60
1.49	W. Watertown Plank Road	701.57	704.95	707.52	708.44
1.53		703.20	705.72	707.91	708.75
1.535		703.30	705.01	707.19	708.16
1.59		704.60	706.37	707.56	708.41
1.595		704.64	706.63	707.95	708.75
1.62		705.04	707.20	708.54	709.26

6

Table 2 (continued)

		Flood Stage Elevation (feet above NGVD 1929)			
(River Mile)	Description	Two-Year	10-Year	50-Year	100-Year
1.63		704.99	707.09	708.38	709.11
1.635		705.99	707.55	708.68	709.08
1.69		707.30	709.00	710.22	710.64
1.695		707.39	708.95	710.09	710.48
1.76		708.82	710.53	711.76	712.18
1.79		709.03	710.74	711.95	712.36
1.86		709.40	711.12	712.33	712.74
1.87		709.27	710.58	711.25	711.72
1.8725	N. 115th Street (bridge)				
1.875		709.64	717.25	717.50	719.57
1.88		709.59	717.62	718.21	720.28
1.97		711.49	717.76	718.41	720.38
2.06		712.03	717.80	718.45	720.37
2.15		712.49	717.87	718.56	720.44
2.19		712.75	717.91	718.61	720.45
2.21		712.88	718.05	718.89	720.70
2.24		713.01	718.00	718.80	720.61
2.34		713.94	718.50	719.57	721.25
2.42	· · ·	714.24	718.66	719.75	721.35
2.5		714.56	718.61	719.64	721.24

Source: SEWRPC.

The increases in the 100-year flood stage of Underwood Creek that would result from removal of the concrete lining can be addressed in two ways: 1) by providing additional conveyance and/or storage capacity to reduce flood stages to levels equal to or below the existing levels, or 2) by obtaining easements from all property owners affected by the stage increases.⁶ It is also possible that a combination of those two approaches could be applied.

Description of Stream Reaches

The following is a description of the opportunities and limitations for the mitigation of flood stage increases due to removal of the concrete lining along Underwood Creek. River mile locations are shown on Map 2. The entire reach of Underwood Creek from its mouth upstream to the Milwaukee-Waukesha county line and the entire reach of the South Branch of Underwood Creek from its mouth to the enclosure outlet at Theodore Trecker Way are contained within primary environmental corridors. Much of the land adjacent to the streams is Milwaukee County park land. The presence of wetlands is noted at various places along the reach because modification of those areas would require special consideration regarding State permitting requirements.

Only sites along Underwood Creek were evaluated for the provision of floodwater storage under Alternative Plans B and C. Lands along both Underwood Creek and the South Branch of Underwood Creek were evaluated as possible sites for the provision of floodwater storage under Alternative Plans EE, EP, and FP.

⁶The procurement of easements would only be a reasonable approach for properties where there would be no flooding of buildings.

Table 3

UNDERWOOD CREEK FINAL FLOOD STAGES: EXISTING CHANNEL WITH PLANNED YEAR 2020 LAND USE CONDITIONS

Location		Flood Stage Elevation (feet above NGVD 1929)			
(River Mile)	Description	Two-Year	10-Year	50-Year	100-Year
0.06		672.76	675.37	676.80	677.30
0.11	· · · ·	673.05	675.65	677.04	677.52
0.22		673.73	676.38	677.84	678.32
0.225		675.49	677.48	678.77	679.26
0.23		675.87	678.18	679.69	680.29
0.33		677.87	680.40	682.44	682.97
0.42		678.46	681.02	682.98	683.48
0.468		679.22	682.05	684.07	684 69
0.475		679.53	682.47	684.54	685.20
0.49		679.79	682.81	684.88	685.54
0.491		679.69	682.72	684.81	685.48
0.495		679.66	682.71	684.83	685.51
0.52		679.80	682.82	684.91	685.59
0.63		680.17	683.00	684.98	685.62
0.635		680.07	681.82	683.98	684.63
0.67		680.97	683.33	684.97	685.63
0.675	· · · · · ·	684.29	686.00	687.36	687.81
0.72		685.69	687.93	689.38	689.87
0.725		685.69	687.93	689.38	689.87
0.73		685.10	687.35	688.84	689.33
0.74	Downstream USH 45	686.10	688.72	690.36	690.93
0.76	Upstream USH 45	686.25	688.84	690.46	691.02
0.8		687.05	689.94	691.73	692.38
0.805		689.52	691.42	692.81	693.32
0.81		690.77	692.97	694.41	694.79
0.8125	Canadian Pacific Railway (bridge)				
0.815		691.91	694.95	698.42	701.44
0.82		692.86	695.92	699.15	701.60
0.83		692.92	696.00	699.24	701.66
0.94		692.85	695.88	699.19	701.62
1.04		693.13	695.80	699.04	701.51
1.14		693.84	696.28	699.30	701.68
1.26		694.81	696.61	699.07	701.42
1.27	Downstream Mayfair Road	696.01	698.45	700.40	702.24
1.275	Upstream Mayfair Road	696.03	698.46	700.41	702.25
1.28		695.24	697.67	699.81	701.88
1.37		697.02	699.16	700.71	702.25
1.45		697.36	699.53	701.04	702.42
1.46		698.64	700.59	701.84	702.27
1.461	Union Pacific Railroad	699.71	702.04	703.61	704.22
1.462		699.99	702.34	703.91	704.51
1.47		701.81	705.40	707.83	708.72
1.49	W. Watertown Plank Road	701.65	705.10	707.66	708.56
1.53		703.28	705.84	708.03	708.87
1.535		703.36	705.08	707.34	708.30
1.59		704.67	706.43	707.69	708.53
1.595		704.71	706.70	708.07	708.87

Logation		Flood Stage Elevation (feet above NGVD 1929)			
(River Mile)	Description	Two-Year	10-Year	50-Year	100-Year
1.62		705.11	707.29	708.64	709.37
1.63		705.07	707.17	708.49	709.22
1.635		706.05	707.61	708.74	709.13
1.69		707.37	709.07	710.28	710.70
1.695		707.45	709.01	710.14	710.53
1.76		708.88	710.60	711.82	712.23
1.79		709.10	710.80	712.01	712.41
1.86		709.46	711.18	712.39	712.79
1.87		709.33	710.62	711.33	711.79
1.8725	N. 115th Street (bridge)				÷ -
1.875		709.61	717.67	717.80	719.87
1.88		709.66	718.04	718.51	720.58
1.97		711.57	718.16	718.69	720.67
2.06		712.11	718.19	718.72	720.66
2.15		712.56	718.26	718.83	720.72
2.19		712.82	718.29	718.87	720.74
2.21		712.95	718.43	719.14	720.97
2.24		713.08	718.38	719.05	720.88
2.34		714.03	718.85	719.80	721.51
2.42		714.33	718.99	719.97	721.61
2.5		714.65	718.94	719.85	721.49

Table 3 (continued)

Source: SEWRPC.

As shown on Map 2, 16 potential floodwater storage areas were identified in the preliminary draft of the Underwood Creek section of the MMSD watercourse plan report for the Menomonee River watershed. That report was prepared for the District by Camp, Dresser & McKee (CDM) and the most current version was provided to the Commission staff by MMSD staff in August 2000. That analysis was performed to evaluate alternative storage areas in the Underwood Creek subwatershed that could reduce or eliminate the need for the retention basins on the Milwaukee County Grounds that are proposed under the watercourse system plan. That report concluded that the storage sites do not provide viable alternatives to the proposed retention basins. However, under this study, the sites were considered in the evaluation of potential compensating storage areas that would be part of a plan to remove the concrete lining from Underwood Creek.

Along Underwood Creek, six of the sites are located in the City of Wauwatosa (Sites 2, 3, 4, 12, 15, and 16), three are located in the Village of Elm Grove (Sites 9, 10, and 13), and one is located in the City of Brookfield (Site 11). Along the South Branch of Underwood Creek, one is located in the City of Wauwatosa (Site 5) and three (Sites 6 through 8) are located in the City of Brookfield. The remaining two sites (Sites 1 and 14) are located adjacent to the Menomonee River. Site 1 is the Milwaukee County Hoyt Park swimming pool and Site 14 apparently includes part of the Milwaukee County Grounds retention basins that are proposed under the MMSD watercourse system plan and part of an existing wet detention basin. The Hoyt Park site could not be reasonably developed because such development would eliminate an important County recreational facility and the County Grounds site is already specified for use as a storage area. Thus, the two Menomonee River sites were dropped from further consideration for this study.





Scale: 1 Inch Horizontal = 0.2 Miles 1 Inch Vertical = 10 Feet

Source: SEWRPC.

UNDERWOOD CREEK 100-YEAR RECURRENCE INTERVAL FLOOD PROFILE FOR PLANNED (2020) LAND USE AND EXISTING CHANNEL CONDITIONS



Scale: 1 Inch Horizontal = 0.2 Miles 1 Inch Vertical = 10 Feet

Source: SEWRPC.



The three Underwood Creek sites in the Village of Elm Grove and the one Underwood Creek site in the City of Brookfield were all evaluated under the SEWRPC stormwater and floodland management plan for those communities. Of those four sites, significant portions of three (Sites 10, 11, and 13) are within the 100-year floodplain of Underwood Creek and currently provide considerable floodwater storage volume. In addition, the stormwater and floodland management plan recommends increasing the floodwater storage volume in the vicinity of Site 11, which is north of W. North Avenue, and at Site 10, which is in the Elm Grove Village Park. Thus, Sites 10, 11, and 13 are included in the analysis set forth herein since they are incorporated in the stormwater and floodland management plan. The fourth site is located on the grounds of the School Sisters of Notre Dame convent in Elm Grove and it was found to be impractical and ineffective as a storage site based on the analyses made for the stormwater and floodland management plan. Thus, that site was eliminated from consideration.

The remaining 10 sites identified in the watercourse plan report are Sites 2 through 4, 12, 15, and 16 along Underwood Creek and Sites 5 through 8 along the South Branch of Underwood Creek. Those 10 sites are evaluated and described below.

- Underwood Creek Reach from River Mile 0.00 at the Confluence with the Menomonee River to River Mile 0.22-In this reach the 100-year flood stage is governed by backwater from the Menomonee River under existing channel conditions. The Canadian Pacific Railway is located along the south side of the stream and in some places it is only about 60 feet from the stream. Milwaukee County park land, including George Hansen golf course, is located between the railway and the stream near the confluence (Site 2) and south of the railway upstream from River Mile 0.11 (the eastern portion of Site 3). The Serafino Square apartment complex is located north of the stream with some buildings within less than 50 feet of the low flow channel. The Milwaukee County site that is designated for the provision of centralized retention storage under the District's watercourse system plan is located to the southeast of this reach. Much of Hansen golf course is within the existing condition 100-year floodplain and, therefore, it provides significant floodwater storage capacity under existing conditions.⁷ Physical alteration of the golf course site to provide additional storage volume would be likely to destroy the golf course, eliminating an important recreational facility in the Milwaukee County Park system. Thus, the provision of additional floodwater storage on the golf course is not considered to be feasible. In general, there is little potential for the provision of additional floodwater storage capacity in this reach outside of the site already identified under the watercourse system plan for the provision of downstream flood damage reduction along the Menomonee River.
- <u>Underwood Creek Reach from River Mile 0.22 to River Mile 0.46</u>—The railway is located about 50 feet south of the low flow channel in this reach and Hansen golf course is located south of the railroad (middle portion of Site 3). In this reach, much of the golf course is designated as wetland. North of the stream at the easternmost end of this reach are one commercial property and a church where there might be the potential for the creation of some floodwater storage in existing open space and parking areas. To the east of those properties along the north side of the stream and south of Fisher Parkway are seven residences with garages and houses that are within about 25 and 60 feet, respectively, from the low flow channel. With the limited exception noted above, there is no reasonable potential for the provision of additional floodwater storage along this reach. Buildings and properties could be purchased to provide a suitably large site, but such acquisitions may not be justifiable given the project objectives as set forth in Appendix A.
- <u>Underwood Creek Reach from River Mile 0.46 to River Mile 0.73 on the Downstream Side of USH 45</u>—The railway is located about 100 feet, or less, southeast of the low flow channel in this reach. The western end of the Hansen golf course wetland (extreme western portion of Site 3) and

⁷A portion of the old stream channel traverses the golf course from west to east.</sup>

generally steeply sloping, wooded County park land outside of the wetland are located southeast of the railway. To the northwest of the stream, Fisher Parkway is within 100 feet, or less, from the low flow channel and single-family residences are located on the opposite side of Fisher Parkway. Once again, there is little potential for the provision of additional floodwater storage in this reach.

- <u>Underwood Creek Reach from River Mile 0.73 on the Downstream Side of USH 45 to River Mile</u> <u>1.26 on the Downstream Side of STH 100 (Mayfair Road)</u>—The Canadian Pacific railway crosses the stream just upstream of USH 45 and it is located 50 to 100 feet west of the low flow channel through most of this reach. Commercial development is located immediately to the west of the railway in the first 0.2 mile upstream of USH 45. The east bank in the 0.5-mile-long reach between USH 45 and STH 100 is generally a steeply sloping, wooded, primary environmental corridor (Site 12). The only possibility for the creation of floodwater storage and/or conveyance on existing open land in this reach would be to cut into the hillside along the primary environmental corridor.
- <u>Underwood Creek Reach from River Mile 1.26 on the Downstream Side of STH 100 to River Mile 1.53 on the Upstream Side of Watertown Plank Road</u>—Between STH 100 and W. Watertown Plank Road the stream flows through a narrow 100 to 200-foot-wide corridor with the railway on the west and the STH 100 and W. Watertown Plank Road embankments and a commercial property on the east. The Milwaukee County Oak Leaf bicycle trail runs along the east side of the stream in this reach. There is no reasonable potential for the provision of additional floodwater storage and/or conveyance along this reach.
- Underwood Creek Reach from River Mile 1.53 on the Upstream Side of Watertown Plank Road to River Mile 1.86 on the Downstream Side of N. 115th Street—The railway is less than 100 feet north of the low flow channel throughout this reach. The Milwaukee County Oak Leaf bicycle trail runs along the south side of the stream in this reach. The outfall from the old Underwood Creek channel is located in this reach at approximate River Mile 1.62. The land along the old channel north of the railway is designated as wetland.⁸ There is the potential for the creation of some overbank floodwater storage capacity southeast of the stream on the grounds of Underwood Elementary School (Site 4). Much of the available open area on the school grounds is currently occupied by three baseball and softball diamonds and two soccer fields, all of which are frequently in use. Any floodwater storage area would have to be designed with extensive special features to enable the continued use of those facilities.
- <u>Underwood Creek Reach from River Mile 1.86 on the Downstream Side of N. 115th Street to River Mile 2.24 Near N. 121st Street Extended</u>—In this reach, the railway runs parallel to and north/northwest of the stream within 60 to 70 feet of the low flow channel. The inlet to the old Underwood Creek channel is located at River Mile 2.21. The lands adjacent to the old channel are designated as wetlands (Site 16) and residential development is located along Diane Drive along the north edge of the wetlands. The Diane Drive area has experienced sanitary sewer backups into the basements of residences, but it does not experience direct flooding caused by overflow from Underwood Creek, or the old channel. There is an approximately 150-foot-wide band of open space on Milwaukee County park property extending from the Underwood Creek low flow channel to

⁸Considering that: 1) it is likely that the lands along the old channel will be recommended to be designated as floodplain when future floodplain map updates are made and 2) the lands along the old channel are designated as wetlands, the area along the old channel is not a desirable location for the provision of additional floodwater storage capacity. Excavation in that area would disturb the wetland and raising the 100-year flood stage to provide more storage would require the procurement of numerous easements from property owners. Thus, this area was assigned a low priority as a possible mitigation storage site.

Underwood Parkway (eastern two-thirds of Site 15). There is the potential for some limited overbank lowering and on-line storage creation in that area.

- Underwood Creek Reach from River Mile 2.24 Near N. 121st Street Extended to the Confluence with the South Branch of Underwood Creek at River Mile 2.54—Downstream of River Mile 2.5 the unconstrained open space along the stream widens to about 300 feet in a strip along the west side of the channel and about 200 feet along the east side (western one-third of Site 15). However, most of that land, including the strips immediately adjacent to the channel, is designated as wetlands. Underwood Parkway and the single-family residences along that street are located to the east of the open lands. An MMSD trunk (interceptor) sewer lift station is located between the stream and Underwood Parkway at about River Mile 2.5. There is the potential for some overbank lowering and on-line storage creation in this reach, but such activities would involve disturbance of wetlands.
- <u>South Branch of Underwood Creek Reach from River Mile 0.00 at the Confluence with Underwood</u> <u>Creek to River Mile 0.14 on the Downstream Side of the Canadian Pacific Railway</u>—Site 5 is located in this reach along the east side of the stream between W. Blue Mound Road and the Railway. That site is a relatively small area that includes a power line transmission tower, a portion of the Milwaukee County Oak Leaf bicycle trail, and a small neighborhood park at its east end in Wauwatosa. A 16-inch-diameter oil pipeline is located near the eastern edge of Site 5. There is little potential for the provision of significant floodwater storage capacity in this reach.
- South Branch of Underwood Creek Reach from River Mile 0.14 on the Downstream Side of the Canadian Pacific Railway to River Mile 0.56 on the Downstream Side of IH 94—Site 6 is located along the east side of the stream and Site 7 is located along the west side of the stream in this reach. Both sites are in the City of Brookfield. Site 6 is a wetland that is partially wooded and includes a portion of the Oak Leaf bicycle trail. Site 7 includes the City of Brookfield's Krueger Park. The park facilities include a baseball diamond, a softball diamond, a soccer field, and a children's play area. Any floodwater storage area would have to be designed with extensive special features to enable the continued use of those facilities. The 16-inch-diameter oil pipeline is located near the eastern edge of Site 6. There is the potential for some overbank lowering and on-line storage creation in this reach, but such activities would involve disturbance of both the park and wetlands. The storage area design would have to accommodate the existing oil pipeline.
- South Branch of Underwood Creek Reach from River Mile 0.56 on the Downstream Side of IH 94 to <u>River Mile 0.78</u>—Underwood Creek Parkway is located about 100 feet east of the low-flow channel of the Creek in this reach and industrial development is located east of the Parkway. Site 8 is located along the west side of the stream. The site is a currently undeveloped portion of the City of Brookfield's Krueger Park. There is the potential for storage creation on Site 8. The City of Brookfield has a policy allowing no net loss of park land. Thus, if development of the site as a storage area would preclude its use as park land, another comparable site would have to be purchased for park or resource protection purposes. The 16-inch-diameter oil pipeline is located near the eastern edge of Site 8. The storage area design would have to accommodate the existing oil pipeline.
- South Branch of Underwood Creek Reach from River Mile 0.78 to the Outfall of the Channel Enclosure at Theodore Trecker Way Extended—Underwood Creek Parkway is located from 100 to 150 feet east and north of the low-flow channel of the South Branch in this reach and industrial development is beyond the Parkway. There is a strip of wetland between the Creek and the Parkway along a portion of this reach and there are wetlands on part of the land north of the Parkway. The area west and south of the South Branch is a wetland. Given these limitations, there is little potential for the provision of significant floodwater storage capacity in this reach.

Review of Preliminary Analyses Developed by MMSD Assuming Removal of the Concrete Lining

Preliminary hydraulic analyses of the impacts of the removal or modification of the concrete lining along Underwood Creek were performed for the District by CDM in 1999. Those analyses were made to obtain an approximate indication of the impacts on the 100-year flood profile of: 1) breaking up the concrete lining and creating a rubble-lined channel with no change in the channel and overbank cross-sections and 2) removing the concrete lining and establishing a more natural channel, again with no change in the channel and overbank cross-sections. The profiles for the two cases would be essentially the same since each would have similar channel roughness characteristics.⁹ Each of the cases considered would result in higher flood profiles relative to existing conditions due to the increased roughness of the channel. However, those increases would be diminished somewhat by the increase in floodwater storage volume in the expanded floodplain. That increase in storage volume would result in some reduction in peak rates of flow. The preliminary analyses by CDM were not intended to quantify the changes in flood flows due to the modifications to the concrete-lined channel. Those analyses served as the starting point for the development of alternative plans by the SEWRPC staff.

Alternative Plan A----Removal of Concrete Lining with Existing Channel Size and Shape Maintained and with Existing Upstream Channel Conditions along the South Branch of Underwood Creek and along Underwood Creek in Waukesha County

Alternative Plan A, which calls for removal of the concrete lining in Underwood Creek and maintenance of the existing channel and overbank size and shape, was developed by the SEWRPC staff as a refinement to the preliminary analysis made by CDM. The reduction in flood flows due to implementation of such an alternative can be seen from a comparison of Tables B-1 and B-4. Also, Tables B-3 and B-5 list two- through 100-year flood stages for planned land use and existing channel conditions and for Alternative A conditions. A comparison of flood stages and the relative changes in stages is set forth in Table B-6 and a comparison of the flood profiles illustrating the impact of implementation of Alternative A is shown in Figure 3. Despite the reduction in flood flows, there would be significant increases of from about 1.0 to 3.4 feet in 100-year flood stages throughout much of the 2.5-mile-long study reach, because of increases in channel roughness.

Areas affected by stage increases would include the Serafino Square apartments and the Fisher Parkway area between River Miles 0.22 and 0.67. During a 100-year flood occurring under existing channel conditions, portions of Fisher Parkway and N. 104th Street would be expected to be flooded. Based on interviews with City of Wauwatosa engineering and public works staff, it was determined that during the large floods of 1997 and 1998¹⁰ storm and sanitary sewers in the neighborhood north of Fisher Parkway surcharged and sanitary sewer backups occurred into basements, but there was no direct overland flooding of structures due to overflow from Underwood Creek. Under Alternative A, in addition to the streets already noted, small portions of N. 102nd, N. 103rd, and N. 106th Streets may also be flooded, along with 19 houses, 34 garages, the lower level of the southeastern apartment building in the Serafino Square complex, and the church building near River Mile 0.23. The stage increase of about one foot near the Milwaukee-Waukesha county line and the confluence with the South Branch of Underwood Creek would also be expected to produce localized increases in the 100-year flood profile in the extreme eastern part of Elm Grove and Brookfield and the downstream reach of the South Branch. Thus, concrete removal without additional mitigative measures would have unacceptable negative impacts and other alternatives were considered, as described in subsequent sections of this report.

⁹The existing channel hydraulic model uses a Manning's roughness coefficient of 0.017 for the concrete channel. Under proposed conditions with a natural or rubble-lined main channel, a roughness coefficient of 0.04 was used.

¹⁰Based on the peak flows recorded at U.S. Geological Survey (USGS) streamflow gauge No. 04087088 located on Underwood Creek at USH 41 in Wauwatosa, the 1997 and 1998 floods are estimated to have recurrence intervals of slightly less than 100 years and about 500 years, respectively.



1 in Horiz. = 0.2 mi 1 in Vert. = 8 ft Source: SEWRPC.

Figure 3 UNDERWOOD CREEK 100-YEAR RECURRENCE INTERVAL FLOOD PROFILES FOR PLANNED (2020) LAND USE AND EXISTING CHANNEL CONDITIONS AND

Alternative Plan B—Removal of Concrete Channel Lining and Overbank Lowering with Existing Upstream Channel Conditions along the South Branch of Underwood Creek and along Underwood Creek in Waukesha County

As shown on Map 3, Alternative Plan B assumes that the concrete lining in Underwood Creek would be removed and that the overbanks beyond the current limits of the lining would be lowered. A comparison of typical existing and proposed channel and overbank cross-sections in each reach is shown in Figures 4 through 6. Underwood Creek flood flows and stages with this alternative implemented are set forth in Tables B-7 and B-8, respectively. A comparison of the changes in flood stages relative to planned land use, existing channel conditions is given in Table B-6.

The modifications to the overbanks would provide both floodwater storage volume and increased hydraulic capacity. The existing streambed profile was assumed to be maintained. Transverse overbank slopes, perpendicular to the direction of flow were assumed to be quite flat, ranging from 0.2 percent to 1.5 percent. The transition between the flat overbank bottom and the existing grade at the outside limit of the overbank was assumed to occur at a slope of one vertical on four horizontal. It was assumed that bridges and culverts would remain the same as under existing conditions. The reaches where overbank lowering was assumed, as described in the previous section, were:

- River Mile 0.23 to 0.33 in the left (north) overbank
- River Mile 0.83 to 1.26 in the right (east) overbank
- River Mile 1.53 to 1.86 in the right (south) overbank
- River Mile 1.88 to 2.5 in the right (south and east) overbank

River Mile 0.23 to 0.33 in the Left (north) Overbank

In this reach, it was assumed that overbank lowering could be accomplished to the south of a commercial property and a church property located along W. North Avenue. As shown on Map 3, such lowering would require reconstruction of the existing parking lots at a lower elevation. Under existing conditions, some minor, shallow flooding would be expected on the parking lots during a 100-year flood. Under proposed conditions, flooding on the parking lots would be expected to depths between 2.5 and six feet. Floodwaters would be stored on the parking lots during storms with recurrence intervals of about two years or more. An additional 13 acre-feet of floodwater storage would be provided on this site during a 100-year recurrence interval flood. The provision of overbank floodwater storage would probably not be practical at this location due to the depths and frequency of flooding and because the church building would be added to the 100-year floodplain if this alternative were implemented.

River Mile 0.83 to 1.26 in the Right (east) Overbank

As shown on Map 3 and Figure 4, the existing overbank would be extended into the wooded primary environmental corridor to the east of the channel between the Canadian Pacific Railway and STH 100 (Mayfair Road). The overbank excavation would extend to a height of about 30 feet above the streambed, or from four to 20 feet below the crest of the hillside. Some flooding of the lowered overbank would be expected even during floods with recurrence intervals less than two years. An additional 13 acre-feet of floodwater storage would be provided in this reach during a 100-year recurrence interval flood.

River Mile 1.53 to 1.86 in the Right (south) Overbank

As shown on Map 3 and Figure 5, from W. Watertown Plank Road to the downstream side of N. 115th Street, the right overbank would be lowered between the channel and the athletic fields on the Underwood School property.

ALTERNATIVE B

REMOVAL OF CONCRETE CHANNEL LINING AND OVERBANK LOWERING WITH EXISTING UPSTREAM CHANNEL CONDITIONS ALONG THE SOUTH BRANCH OF UNDERWOOD CREEK AND ALONG UNDERWOOD CREEK IN WAUKESHA COUNTY

ALTERNATIVE C

REMOVAL OF CONCRETE CHANNEL LINING AND OVERBANK LOWERING WITH EXISTING UPSTREAM CHANNEL CONDITIONS ALONG THE SOUTH BRANCH OF UNDERWOOD CREEK AND RECOMMENDED FLOODLAND MANAGEMENT MEASURES IN THE CITY OF BROOKFIELD AND THE VILLAGE OF ELM GROVE

LEGEND



Мар З



Map 3 (continued)



	LEGEND
1.62	DISTANCE FROM MOUTH IN RIVER MILES
<u>→ ^{54"} (</u>	EXISTING CULVERT AND SIZE
	PRIMARY ENVIRONMENTAL CORRIDOR BOUNDAR
	WETLAND BOUNDARY
	PROPOSED OVERBANK LOWERING AREA
RCP	REINFORCED CONCRETE PIPE
CMP	CORRUGATED METAL PIPE

MMSD UNDERWOOD CREEK CONCRETE REMOVAL EVALUATION RIVER MILE 1.14-COMPARISON OF EXISTING AND ALTERNATIVES B AND C CHANNEL



1 inch Horiz. = 60 Feet 1 inch Vert. = 20 Feet

Source: SEWRPC.

MMSD UNDERWOOD CREEK CONCRETE REMOVAL EVALUATION RIVER MILE 1.62-COMPARISON OF EXISTING AND ALTERNATIVES B AND C CHANNEL



1 inch Horiz. = 50 Feet 1 inch Vert. = 20 Feet

Source: SEWRPC.

MMSD UNDERWOOD CREEK CONCRETE REMOVAL EVALUATION RIVER MILE 2.15-COMPARISON OF EXISTING AND ALTERNATIVES B AND C CHANNEL



¹ inch Horiz. = 40 Feet 1 inch Vert. = 20 Feet

The athletic fields would not be altered under this alternative.¹¹ Flooding of the lowered overbank would generally be expected during floods with recurrence intervals of about two years or more. An additional 11 acrefeet of floodwater storage would be provided in this reach during a 100-year recurrence interval flood.

River Mile 1.88 to 2.5 in the Right (south and east) Overbank

As shown on Map 3, this reach extends from the upstream side of N. 115th Street through River Mile 2.5, which is just downstream from the confluence with the South Branch and the Milwaukee-Waukesha county line. Figure 6 shows the channel and overbank cross-section. At the upstream end of the reach, the limits of the overbank lowering are constrained by the existing MMSD lift station. The assumed overbank lowering in this reach would require excavation in a wetland near the upstream end of the reach as shown on Map 3. Some flooding of the lowered overbank would be expected even during floods with recurrence intervals less than two years. An additional seven acre-feet of floodwater storage would be provided in this reach during a 100-year recurrence interval flood.

Streambank and Streambed Protection

Along about 1.36 miles, or 54 percent of the 2.54-mile-long reach of Underwood Creek, it was found that average channel streamflow velocities could exceed six feet per second, with some being as great 13 feet per second under this alternative. Bank and bed stabilization, perhaps through a combination of bio-engineering and riprap or gabion protection, would be required in those reaches of high erosion potential.

There are several locations where flow velocities would approach or exceed 10 feet per second during floods. Those locations include the N. 115th Street culverts and the bridges at Watertown Plank Road, the Union Pacific Railway, the Canadian Pacific Railway, and USH 45. Special erosion control treatment, perhaps involving "hard" armoring solutions are likely to be required at those locations.

Effects of Implementation of the Alternative Plan

As seen from Table B-6 and Figure 7, the implementation of this alternative would increase 100-year recurrence interval flood stages by between 0.2 and 2.9 feet in the reach between River Mile 0.67 and the mouth. That reach includes the Fisher Parkway area, one commercial property, a church, and the Serafino Square apartments. Thus, under Alternative B, in addition to portions of Fisher Parkway and N. 104th Street which would be expected to be flooded during a 100-year flood occurring under existing channel conditions, the church building near River Mile 0.23, the lower level of the southeastern apartment building in the Serafino Square complex, small portions of N. 102nd and N. 106th Streets, and 11 houses and 30 garages may also be flooded. Thus, even with the mitigative overbank lowering measures, this alternative plan would have negative street and structural flooding impacts.

In general, in the 1.8-mile-long reach from USH 45 upstream to the Milwaukee-Waukesha county line, 100-year flood stages would be reduced by as much as three feet in comparison to existing channel conditions. However, there would still be some stage increases in the vicinity of W. Mayfair Road and W. Watertown Plank Road. No flooding of streets or buildings would be caused by those stage increases. Reduced 100-year flood stages at River Mile 2.21 would result in less overflow into the old Underwood Creek channel in comparison to existing channel conditions. Thus, the 100-year flood profile would be lowered along the old channel.

The 100-year flood stage would decrease by about two feet near the Milwaukee-Waukesha county line and the confluence with the South Branch of Underwood Creek, resulting in localized flood profile decreases in the extreme eastern parts of Elm Grove and Brookfield and along the downstream reach of the South Branch.

¹¹Alternative Plans EE, EP, and FP include creation of floodwater storage on the Underwood Elementary School athletic fields.

UNDERWOOD CREEK 100-YEAR RECURRENCE INTERVAL FLOOD PROFILES FOR PLANNED (2020) LAND USE AND EXISTING CHANNEL CONDITIONS AND ALTERNATIVE B: REMOVAL OF CONCRETE LINING AND OVERBANK LOWERING WITH EXISTING UPSTREAM CHANNEL CONDITIONS ALONG THE SOUTH BRANCH OF UNDERWOOD CREEK AND ALONG UNDERWOOD CREEK IN WAUKESHA COUNTY



Costs of Alternative Plan B

As set forth in Table 4, the capital cost of Alternative Plan B is estimated to be \$20,500,000 dollars. The annual operation and maintenance cost is estimated to be \$205,000. Assuming an annual interest rate of 6 percent and a project life and amortization period of 50 years, the average annual cost is \$1,507,000.

Alternative Plan C—Removal of Concrete Channel Lining and Overbank Lowering with Existing Upstream Channel Conditions along the South Branch of Underwood Creek and Recommended Floodland Management Measures in the City of Brookfield and the Village of Elm Grove

The only difference between Alternative Plans B and C is the inclusion of the recommended floodland management measures in the City of Brookfield and the Village of Elm Grove overflow channel under Alternative Plan C. As set forth in SEWRPC CAPR No. 236, the recommended plan calls for the provision of a 23-acre-foot wet detention basin in the headwaters of Dousman Ditch in the City of Brookfield; a 14-acre-foot compensating floodwater storage area along Underwood Creek northwest of the intersection of W. North Avenue and Lilly Road in Brookfield; a 35-acre-foot compensating floodwater storage area in the Elm Grove Village Park west of Underwood Creek; an approximately 0.9-mile-long overflow channel located west of, and parallel to Underwood Creek between Creekwood Court and Juneau Boulevard in Elm Grove; and an approximately one-mile-long double six-foot-high by seven-foot-wide reinforced concrete box culvert to convey flood overflows from Underwood Creek between Juneau Boulevard and a proposed outfall just east of the Milwaukee-Waukesha county line.¹²

The overflow channel alternative in the Village was designed to produce no downstream increases in flood flows and stages under existing channel conditions in the City of Wauwatosa. Thus, the flood flows and stages and the potential downstream impacts along Underwood Creek in Wauwatosa are essentially the same under Alternative Plan C as under Alternative Plan B. Underwood Creek flood flows and stages with Alternative Plan C implemented are set forth in Tables B-9 and B-10, respectively. A comparison of the changes in flood stages relative to planned land use, existing channel conditions is given in Table B-6 and is shown graphically on Figure 8.

As set forth in Table 4, the capital cost of Alternative Plan C is estimated to be \$20,500,000 dollars.¹³ The annual operation and maintenance cost is estimated to be \$205,000. Assuming an annual interest rate of 6 percent and a project life and amortization period of 50 years, the average annual cost is \$1,507,000.

¹²At the time that this report was issued, the Commission staff was in the process of analyzing refinements to the recommended floodland management plan that is described in CAPR No. 236. Those analyses were requested by the Village of Elm Grove. The possible refinements that are being investigated include: 1) providing additional floodwater storage along Underwood Creek just upstream of the Milwaukee-Waukesha county line; 2) shortening the double box diversion culvert so it discharges to Underwood Creek in the Village of Elm Grove upstream of the additional storage area, 3) shortening the overflow channel to avoid, or reduce, wetland disturbance; and 4) reconfiguring the compensating storage area in the Village Park to avoid wetland disturbance and reduce disruption of the Park. As is the case with the recommended plan in CAPR No. 236, all refined analyses are being designed to produce no downstream increases in flood flows and stages under existing channel conditions in the City of Wauwatosa.

¹³The capital cost of the recommended floodland management plan for Underwood Creek in the City of Brookfield and the Village of Elm Grove is not included in this amount because the measures called for in Brookfield and Elm Grove do not affect the measures needed in Milwaukee County under Alternative Plan C. That is, the two plans can be implemented independently. Also, it is assumed that the costs in Brookfield and Elm Grove would be borne by those communities.
COSTS OF ALTERNATIVE PLANS FOR REMOVAL OF THE CONCRETE LINING IN UNDERWOOD CREEK

Alternatives		Project Component	Estimated Capital Cost ^a	Annual Operation and Maintenance Cost	Average Annual Cost		
Alternative B-Removal of Concrete Channel Lining and	1.	Removal of concrete lining along 2.54 miles of Underwood Creek	\$ 1,500,000				
Overbank Lowering with Existing Upstream Channel	2.	Overbank lowering along 1.5 miles of Underwood Creek	6,950,000				
Conditions along the South Branch of Underwood Creek and along Underwood Creek	3.	Bicycle trail reconstruction (1,850 feet)	50,000				
in Waukesha County and Alternative C—Removal of Concrete Channel Lining and Overbank Lowering with Existing Upstream Channel Conditions along the South Branch of Linderwood Crock	4.	Low flow channel construction and channel restoration ^b	12,000,000				
and Recommended Flood- land Management Measures in the City of Brookfield and the Village of Elm Grove							
		Total	\$20,500,000	\$205,000	\$1,507,000		
Alternative EE—Removal of Concrete Channel Lining,	1.	Removal of concrete lining along 2.54 miles of Underwood Creek	\$ 1,500,000				
Expanded Overbank Lower- ing along Underwood Creek, Overbank Lowering along	2.	Overbank lowering along 1.4 miles of Underwood Creek	7,230,000				
the South Branch, Culvert Replacement or Modifica- tion, and Existing Upstream	3.	Restoration of athletic fields at Underwood Elementary School in the City of Wauwatosa	200,000				
Channel Conditions along Underwood Creek in Waukesha County	4.	Overbank lowering along 0.6 mile of the South Branch of Underwood Creek	8,230,000				
	5.	Restoration of athletic fields and playground at Krueger Park in the City of Brookfield	200,000				
	6.	Structure replacement or modification at N. 115th Street	200,000				
	7.	Bicycle trail reconstruction (3,450 feet)	95,000				
	8.	Low flow channel construction and channel restoration ^b	12,000,000				
• •		Total	\$29,655,000	\$110,000	\$1,993,000		
Alternative EP-Removal of Concrete Channel Lining,	1.	Removal of concrete lining along 2.54 miles of Underwood Creek	\$ 1,500,000				
Expanded Overbank Lower- ing along Underwood Creek, Overbank Lowering and		Overbank lowering along 1.4 miles of Underwood Creek	7,230,000				
Retention Basin along the South Branch, Culvert Replacement or Modifica-	3.	Restoration of athletic fields at Underwood Elementary School in the City of Wauwatosa	200,000				
Channel Conditions along Underwood Creek in Waukesha County	4.	Overbank lowering along 0.4 mile of the South Branch of Underwood Creek	4,500,000				

Alternatives	Project Component	Estimated Capital Cost ^a	Annual Operation and Maintenance Cost	Average Annual Cost
Alternative EP (continued)	 Restoration of athletic fields and playground at Krueger Park in th City of Brookfield 	e 200,000		
	 Retention basin at Site 8 along the South Branch of Underwood Creel 	8,580,000		
	7. Structure replacement or modification at N. 115th Street	190,000		
	8. Bicycle trail reconstruction (3,450 feet)	95,000		
	9. Low flow channel construction and channel restoration ^b	12,000,000		
	Total	\$34,495,000	\$110,000	\$2,300,000
Alternative FP-Removal of Concrete Channel Lining,	1. Removal of concrete lining along 2.54 miles of Underwood Creek	\$ 1,500,000		
Streambed Lowering and Expanded Overbank Lower-	2. Overbank lowering along 1.0 mile of Underwood Creek	5,380,000		
Overbank Lowering and Retention Basin along the South Branch, Culvert	3. Restoration of athletic fields at Underwood Elementary School i the City of Wauwatosa	200,000 n		
Replacement or Modifica- tion, and Existing Upstream Channel Conditions along	4. Overbank lowering along 0.4 mile of the South Branch of Underwood Creek	4,500,000		
Underwood Creek in Waukesha County	5. Restoration of athletic fields and playground at Krueger Park in th City of Brookfield	e 200,000		
	6. Retention basin at Site 8 along the South Branch of Underwood Creel	8,580,000		
	7. Structure replacement or modification at N. 115th Street	190,000		
	8. Streambed lowering along 1.45 miles of Underwood Creek	1,000,000	· · · · ·	
	9. Low flow channel construction and channel restoration ^b	12,170,000		
	10. Bicycle trail reconstruction (3,450 feet)	95,000		
	11. One- to four-foot high, 460-foo long floodwall and interior drainage facilities	265,000		
	Total	\$34,080,000	\$ 75,000	\$2,239,000

^aCosts are for 2000 <u>Engineering News-Record</u> Construction Cost Index = 7,230.

^bThe unit cost for this component is consistent with those used for the District's Menomonee River watercourse system plan. Source: SEWRPC.





Alternative Plan EE—Removal of Concrete Channel Lining, Expanded Overbank Lowering along Underwood Creek, Overbank Lowering along the South Branch, Culvert Replacement or Modification, and Existing Upstream Channel Conditions along Underwood Creek in Waukesha County

Alternative Plan EE assumes that the concrete lining in Underwood Creek would be removed and that the overbanks beyond the current limits of the lining would be lowered. As shown on Map 4, the mitigative measures which are called for under Alternative Plan EE expand on those measures called for under Alternative Plans B and C. Alternative Plan EE calls for removal of the Underwood Creek concrete channel lining, overbank lowering along the South Branch of Underwood Creek in Brookfield, expanded overbank lowering along Underwood Creek in Wauwatosa, culvert replacement or modification at N. 115th Street, and maintenance of the existing upstream channel conditions in Waukesha County. Overbank lowering at the church and commercial parking lots in the reach between River Mile 0.23 to 0.33 of Underwood Creek was judged to be impractical as described above relative to Alternative Plan B, and it was, therefore, eliminated under this alternative. A comparison of typical existing and proposed channel and overbank cross-sections in each reach is shown on Figures 9 through 11. Underwood Creek flood flows and stages with this alternative implemented are set forth in Tables 5 and 6, respectively. A comparison of the changes in flood stages relative to planned land use, existing channel conditions is given in Table 7.

Relative to existing channel conditions, the overall flood storage volume during a 100-year flood would be increased from 380 acre-feet to 428 acre-feet, or an increase of about 13 percent along Underwood Creek, and from 91 acre-feet to 188 acre-feet, or an increase of about 107 percent along the South Branch of Underwood Creek. No modification of the Underwood Creek low-flow channel was assumed and the existing streambed profile was assumed to be maintained. Transverse overbank slopes, perpendicular to the direction of flow were assumed to be quite flat, ranging from 0.2 percent to 1.5 percent. The transition between the flat overbank bottom and the existing grade at the outside limit of the overbank was assumed to occur at a slope of one vertical on four horizontal. It was assumed that all bridges and culverts, except the culverts under N. 115th Street, would remain the same as under existing conditions. Relative to Alternative Plan B, the additional measures called for under this plan are the following:

- 1. Expanded overbank lowering in the right (south) overbank on the Underwood Elementary School site between River Mile 1.53 and 1.86
- 2. Overbank lowering along the South Branch of Underwood Creek
- 3. Structure replacement or modification at N. 115th Street

Expanded Overbank Lowering on the Underwood Elementary School Site between River Mile 1.53 and 1.86

In this reach, it was assumed that overbank lowering could be further expanded beyond that called for under Alternative Plans B and C. As shown on Map 4 and Figure 9, lowering of the right overbank would be extended to include the area currently occupied by athletic fields on the Underwood School property. The most northerly athletic fields, including two soccer fields and a baseball diamond, would be lowered and reconstructed to provide additional floodwater storage during floods with recurrence intervals greater than two years. An additional 19 acre-feet of floodwater storage would be provided in this reach during a 100-year recurrence interval flood.

Overbank Lowering along the South Branch of Underwood Creek

Under Alternative Plan EE, overbank lowering along the South Branch of Underwood Creek would extend from River Mile 0.16 through River Mile 0.78. As shown on Map 4, the right (east) overbank in the first 0.12 mile south of the Railway, and the left and right overbanks at Krueger Park in the 0.25-mile-long reach north of the IH 94 crossing would be lowered (see Figures 10 and 11). In addition, the left overbank south of the IH 94 crossing would be lowered to an average elevation of 720.0 feet. An additional 97 acre-feet of floodwater storage would be provided in this reach during a 100-year recurrence interval flood.

Map 4

ALTERNATIVE EE REMOVAL OF CONCRETE CHANNEL LINING, EXPANDED OVERBANK LOWERING ALONG UNDERWOOD CREEK, OVERBANK LOWERING ALONG THE SOUTH BRANCH OF UNDERWOOD CREEK, CULVERT REPLACEMENT OR MODIFICATION, AND EXISTING UPSTREAM CHANNEL CONDITIONS ALONG UNDERWOOD CREEK IN WAUKESHA COUNTY



31



	LEGEND
1.62	DISTANCE FROM MOUTH IN RIVER MILES
<u>, 54"</u> (EXISTING CULVERT AND SIZE
	CULVERT REPLACEMENT OR MODIFICATION
	PRIMARY ENVIRONMENTAL CORRIDOR BOUNDARY
	WETLAND BOUNDARY
	PROPOSED OVERBANK LOWERING AREA
RCP	REINFORCED CONCRETE PIPE
CMP	CORRUGATED METAL PIPE

NOTE: Plan calls for removal of existing concrete channel lining along Underwood Creek from River Mile 0.00 to River Mile 2.54.



Source: SEWRPC.





Scale: 1 Inch Horizontal = 100 Feet 1 Inch Vertical = 20 Feet

NOTE: This exhibit shows the main changes to the overbank. The stream channel would be rehabilitated to include pool, riffle, and run sequences in a meandering low flow channel along with substrate enhancement and appropriate vegetation.



appropriate vegetation.

MMSD UNDERWOOD CREEK CONCRETE REMOVAL STUDY SOUTH BRANCH OF UNDERWOOD CREEK RIVER MILE 0.43-COMPARISON OF EXISTING AND ALTERNATIVES EE. EP. AND FP CHANNEL CONDITIONS

Source: SEWRPC.

34





Scale: 1 Inch Horizontal = 150 Feet 1 Inch Vertical = 20 Feet

NOTE: This exhibit shows the main changes to the overbank. The stream channel would be rehabilitated to include pool, riffle, and run sequences in a meandering low flow channel along with substrate enhancement and appropriate vegetation.

Source: SEWRPC.

UNDERWOOD CREEK FLOOD FLOWS—EXISTING (1995) AND PLANNED (2020) LAND USE CONDITIONS WITH CONCRETE LINING REMOVED, MAXIMUM EXPANDED CHANNEL CROSS-SECTION ALONG UNDERWOOD CREEK IN WAUWATOSA, AND ALONG THE SOUTH BRANCH OF UNDERWOOD CREEK (ALTERNATIVE EE)

					Recurrence	e Interval			-
		Two	-Year	10-	Year	50-Year		100	-Year
Location (River Mile)	Description	1995 Land Use (cfs)	2020 Land Use (cfs)						
0.00	Confluence with Menomonee River	2,070	2,130	3,740	3,830	5,100	5,200	5,650	5,760
0.76	Upstream side of USH 45	2,050	2,120	3,760	3,860	5,190	5,310	5,770	5,900
1.26	About 590 feet down- stream of Mayfair Road	1,800	1,860	3,220	3,310	4,370	4,480	4,840	4,950
1.53	Upstream side of W. Watertown Plank Road	1,650	1,710	2,900	3,000	3,890	4,020	4,280	4,420
1.62 ^a	Just upstream of location where flow from old channel returns to Underwood Creek	b	1,690	- ⁻ p	2,900	b	3,860	b	4,240
2.21 ^a	Just upstream of location where some flow in Underwood Creek is diverted to old channel	1,650	1,710	2,900	3,000	3,890	4,020	4,280	4,420
2.5	Just downstream from confluence with the South Branch of Underwood Creek	1,470	1,530	2,560	2,670	3,400	3,540	3,720	3,870

^aBetween River Miles 1.62 and 2.21, some flow leaves the main stem of Underwood Creek and enters the old stream channel. The flows at those river mile locations reflect that diversion.

^bNot specifically determined. Requires computation of flood profiles. These flows would be similar to those for 2020 land use conditions.

Source: SEWRPC.

North 115th Street Box Culvert Replacement or Modification

Under this alternative plan, it is proposed to either replace the existing twin 21-foot-wide by 6.8-foot-high reinforced concrete box (RCB) culverts at N. 115th Street with twin 20-foot-wide by 5.8-foot-high RCB culverts, or to modify the existing structure to function hydraulically like a double box culvert of the replacement size. The intention of the replacement or modification is to reduce the hydraulic capacity of the culverts to allow the utilization of greater floodwater storage volume upstream of N. 115th Street. The utilization of that storage would help to reduce downstream increases in the planned land use 100-year flood profile that would occur due to removal of the concrete lining. Reducing the hydraulic capacity at N. 115th is possible because there is no identified direct structure flooding hazard due to overflow from Underwood Creek in the reach upstream from N. 115th Street, thus, there is no need to reduce the 100-year flood profile below that for planned land use, existing channel conditions in that reach.

Streambank and Streambed Protection

Along about 0.81 mile, or 32 percent of the 2.54-mile-long reach of Underwood Creek, it was found that average channel streamflow velocities could exceed six feet per second, with some being as great 16 feet per second under

UNDERWOOD CREEK FLOOD STAGES: PROPOSED ALTERNATIVE EE CHANNEL WITH PLANNED YEAR 2020 LAND USE CONDITIONS^a

		Flood S	tage Elevation (f	eet above NGVD) 1929)
(River Mile)	Description	Two-Year	10-Year	50-Year	100-Year
0.06		675.49	678.13	679.66	680.24
0.11		675.79	678.41	679.93	680.50
0.22		676.50	679.14	680.68	681.24
0.225		676.06	678.76	680.29	680.86
0.23		676.25	678.67	680.05	680.57
0.33		679.13	681.86	683.45	683.98
0.42		680.24	683.05	684.64	685.18
0.468		680.77	683.68	685.39	685.99
0.475		680.90	683.86	685.61	686.22
0.49		681.04	684.02	685.77	686.37
0.491		681.01	683.99	685.74	686.35
0.495		681.01	684.00	685,74	686.35
0.52		681.12	684.08	685.82	686.43
0.63		681.50	684.36	686.07	686.67
0.635		681.38	684.25	685.97	686.58
0.67		682.01	684.58	686.23	686.82
0.675		683.78	685.23	686.03	686.56
0.72		686.27	687.97	689.10	689.46
0.725		686.28	687.97	689.11	689.46
0.73		686.36	687.78	688.55	688.71
0.74	Downstream USH 45	686.78	688.66	689.98	690.50
0.76	Unstream USH 45	687.22	689.31	690.68	691.20
0.8		687.84	690.21	691.76	692.33
0.805	· ·	689.00	690.64	692.05	692.59
0.81		690.19	691.97	693.21	693.67
0.8125	Canadian Pacific Bailway (bridge)				
0.815		691.83	694.60	697.65	698.49
0.82		692.42	695.12	697.95	698.82
0.83		692.57	695.24	698.03	698.91
0.94		693.18	695.68	698.32	699.18
1.04		693.90	695.91	698.38	699.23
1.14		695.07	696.85	698.90	699.68
1.26		695.93	697.04	698.54	699.23
1.27	Downstream Mayfair Road	696.37	697.96	699,45	700.08
1.275	Upstream Mayfair Road	696.45	698.07	699.57	700.19
1.28		696.47	698.05	699.51	700.13
1.37		698.25	700.45	701.83	702.35
1.45	-	698.93	701.24	702.61	703.11
1.46		698.43	700.80	702.13	702.62
1.461	Union Pacific Railroad	699.11	701.08	702.47	702.98
1.462		700.67	703.03	704.63	705.21
1.47		701.61	704.60	706.69	707.46
1.49	W. Watertown Plank Road	701.93	704.83	706.86	707.60
1.53		703.57	706.02	707.81	708.48
1.535		702.89	705.50	707.44	708.14
1.59	-	705.64	707.45	709.00	709.61
1.595		705.61	707.39	708.97	709.59
1.62		706.04	707.81	709.17	709.74
1.63		706.20	708.00	709.31	709.87
1.635		705.56	707.59	709.12	709.72
1.69		708.23	709.29	709.97	710.39
•			-		

Location		Flood S	Stage Elevation (1	eet above NGVE) 1929)
(River Mile)	Description	Two-Year	10-Year	50-Year	100-Year
1.695		707.80	709.14	709.75	710.27
1.76		709.63	710.58	711.00	711.18
1.79		709.86	710.78	711.23	711.41
1.86		710.31	711.16	711.53	711.65
1.87		710.28	710.96	711.00	710.95
1.8725	N. 115th Street (bridge)				
1.875		711.15	714.42	717.72	719.21
1.88		711.39	714.90	718.28	719.80
1.97		712.64	715.59	718.66	720.08
2.06		713.31	715.96	718.84	720.21
2.15		713.92	716.41	719.10	720.41
2.19		714.19	716.59	719.20	720.48
2.21		714.28	716.68	719.27	720.54
2.24		714.44	716.78	719.32	720.58
2.34		714.79	717.00	719.46	720.69
2.42		714.91	717.03	719.48	720.70
2.5		715.61	717.46	719.53	720.68

^aConcrete lining removed in Wauwatosa, expanded channel cross-section in Wauwatosa and along the South Branch of Underwood Creek, and existing channel upstream of Wauwatosa.

Source: SEWRPC.

this alternative. Bank and bed stabilization, perhaps through a combination of bio-engineering and riprap or gabion protection, would be required in some reaches of high erosion potential.

There are several locations where flow velocities would approach or exceed 10 feet per second during floods with recurrence intervals ranging from two through 100 years. Those locations include the N. 115th Street culverts and the bridges at Watertown Plank Road, the Union Pacific Railway, the Canadian Pacific Railway, and USH 45. Special erosion control treatment, perhaps involving "hard" armoring solutions are likely to be required at those locations.

Effects of Implementation of the Alternative Plan

As seen from Table 7 and Figure 12, the implementation of this alternative would increase 100-year recurrence interval flood stages by between 0.3 and 3.0 feet in the potential damage reach between the mouth and River Mile 0.67. That reach includes the Fisher Parkway area, two commercial properties, and the Serafino Square apartments. Under Alternative EE, in addition to portions of Fisher Parkway and N. 104th Street which would be expected to be flooded during a 100-year flood occurring under existing channel conditions, the church building near River Mile 0.23, the lower level of the southeastern apartment building in the Serafino Square complex, small portions of N. 102nd and N. 106th Streets, and 11 houses and 30 garages may also be flooded. Thus, even with the mitigative overbank lowering measures, this alternative plan would have negative street and structural flooding impacts.

In general, in the 1.8-mile-long reach from USH 45 upstream to the Milwaukee-Waukesha county line, 100-year flood stages would be reduced by as much as three feet in comparison to existing channel conditions. However, there would still be some stage increases in the vicinity of the Union Pacific Railroad and W. Watertown Plank Road. No flooding of streets or buildings would be caused by those stage increases. Again, reduced 100-year

COMPARISON OF FLOOD STAGES ALONG UNDERWOOD CREEK

TWO-YEAR RECURRENCE INTERVAL

				Flood Stage Ele	evation (feet abov	e NGVD 1929)		
Location		Two-Year	Two-Year	Change in	Two-Year	Change in	Two-Year	Change in
(River Mile)	Description	Existing ^a	Alternative EE	Stage (feet)	Alternative EP	Stage (feet)	Alternative FP ^b	Stage (feet)
0.06		672.76	675.49	2.73	675.49	2.73	674.88	2.12
0.11		673.05	675.79	2.74	675.79	2.74	675.17	2.12
0.22	· · ·	673.73	676.50	2.77	676.50	2.77	675.64	1.91
0.225		675.49	676.06	0.57	676.06	0.57	675.62	0.13
0.23	·	675.87	676.25	0.38	676.25	0.38	675.69	-0.18
0.33		677.87	679.13	1.26	679.11	1.24	676.47	-1.40
0.42		678.46	680.24	1.78	680.22	1.76	677.29	-1.17
0.468		679.22	680.77	1.55	680.75	1.53	677.90	-1.32
0.475		679.53	680.90	1.37	680.88	1.35	678.02	-1.51
0.49		679.79	681.04	1.25	681.02	1.23	678.08	-1.71
0.491		679.69	681.01	1.32	680.99	1.30	678.08	-1.61
0.495		679.66	681.01	1.35	680.99	1.33	678.09	-1.57
0.52		679.80	681.12	1.32	681.10	1.30	678.19	-1.61
0.63		680.17	681.50	1.33	681.49	1.32	678.42	-1.75
0.635		680.07	681.38	1.31	681.36	1.29	678.41	-1.66
0.67		680.97	682.01	1.04	681.99	1.02	^c	c
0.675		684.29	683.78	-0.51	683.77	-0.52	C	C
0.72		685.69	686.27	0.58	686.26	0.57	°_C	c
0.725		685.69	686.28	0.59	686.26	0.57	C	c
0.73		685.10	686.36	1.26	686.35	1.25	^C	°C
0.74	Downstream USH 45	686.10	686.78	0.68	686.77	0.67	C	c
0.76	Upstream USH 45	686.25	687.22	0.97	687.21	0.96	^C	_ /_c
0.8		687.05	687.84	0.79	687.82	0.77	686.69	-0.36
0.805		689.52	689.00	-0.52	688.99	-0.53	687.58	-1.94
0.81		690.77	690.19	-0.58	690.19	-0.58	688.63	-2.14
0.8125	Canadian Pacific Railway (bridge)							• •
0.815		691.91	691.83	-0.08	691.81	-0.10	690.40	-1.51
0.82		692.86	692.42	-0.44	692.40	-0.46	691.40	-1.46
0.83		692.92	692.57	-0.35	692.56	-0.36	691.41	-1.51
0.94		692.85	693.18	0.33	693.16	0.31	692.53	-0.32
1.04		693.13	693.90	0.77	693.88	0.75	693.91	0.78
1.14		693.84	695.07	1.23	695.06	1.22	695.10	1.26
1.26		694.81	695.93	1.12	695.92	1.11	696.33	1.52
1.27	Downstream Mayfair Road	696.01	696.37	0.36	696.36	0.35	696.55	0.54
1.275	Upstream Mayfair Road	696.03	696.45	0.42	696.44	0.41	696.61	0.58
1.28		695.24	696.47	1.23	696.46	1.22	696.68	1.44
1.37		697.02	698.25	1.23	698.23	1.21	698.13	1.11
1.45		697.36	698.93	1.57	698.91	1.55	698.56	1.20
1.40	Linion Pacific Paitrant	600.71	698.43	-0.21	600.00	-0.23	698.17	-0.47
1 462	Onion Facing Nailf0au	600.00	700 67	-0.60	700 65	-0.62	099.14	-0.57
1.47		701.91	701.61	0.08	700.00	0.00	700.71	0.72
1.49	W Watertown Plank Boad	701.65	701.01	0.20	701.56	-0.23	701.00	-0.15
1.53		703.28	701.93	0.20	701.50	0.25	707.90	0.33
1.535		703.36	702.89	-0.47	702.88	-0.48	703.01	-0.33
1.59		704.67	705.64	0,97	705.62	0.95	705 75	1.08
1.595		704.71	705.61	0,90	705.60	0.89	705.72	1.01
1.62		705.11	706.04	0,93	706.02	0.91	706.14	1.03
1.63		705.07	706.20	1.13	706.19	1.12	706.27	1.20
1.635		706.05	705.56	-0.49	705.55	-0.50	705.59	-0.46
1.69		707.37	708.23	0.86	708.21	0.84	708.26	0,89
1.695		707.45	707.80	0.35	707.79	0.34	707.83	0.38
1.76		708.88	709.63	0.75	709.62	0.74	709.65	0.77
1.79		709.10	709.86	0.76	709.84	0.74	709.88	0.78
1.86		709.46	710.31	0.85	710.30	0.84	710.33	0.87

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			Flood Stage Elevation (feet above NGVD 1929)							
Location (River Mile)	Description	Two-Year Existing ^a	Two-Year Alternative EE	Change in Stage (feet)	Two-Year Alternative EP	Change in Stage (feet)	Two-Year Alternative FP ^b	Change in Stage (feet)		
1.87		709.33	710.28	0.95	710.20	0.87	710.22	0.89		
1.8725	N. 115th Street (bridge)	·		· ·						
1.875		709.61	711.15	1.54	711.21	1.60	711.29	1.68		
1.88		709.66	711.39	1.73	711.58	1.92	711.66	2.00		
1.97		711.57	712.64	1.07	712.70	1.13	712.77	1.20		
2.06		712.11	713.31	1.20	713.34	1.23	713.40	1.29		
2.15		712.56	713.92	1.36	713.93	1.37	713.94	1.38		
2.19		712.82	714.19	1.37	714.19	1.37	714.20	1.38		
2.21	-	712.95	714.28	1.33	714.29	1.34	714.30	1.35		
2.24		713.08	714.44	1.36	714.44	1.36	714.43	1.35		
2.34		714.03	714.79	0.76	714.79	0.76	714.78	0.75		
2.42		714.33	714.91	0.58	714.90	0.57	714.90	0.57		
2.5		714.65	715.61	0.96	715.59	0.94	715.59	0.94		

10-YEAR RECURRENCE INTERVAL

				Flood Stage Ele	vation (Feet abov	e NGVD 1929)		
Location (River Mile)	Description	10-Year Existing ^a	10-Year Alternative EE	Change in Stage (feet)	10-Year Alternative EP	Change in Stage (feet)	10-Year Alternative FP ^b	Change in Stage (feet)
0.06		675.37	678.13	2.76	678.06	2.69	677.94	2.57
0.11		675.65	678.41	2.76	678.35	2.70	678.24	2.59
0.22		676.38	679.14	2.76	679.08	2.70	678.78	2.40
0.225		677.48	678.76	1.28	678.69	1.21	678.75	1.27
0.23		678.18	678.67	0.49	678.61	0.43	678.83	0.65
0.33		680.40	681.86	1.46	681.81	1.41	679.60	-0.80
0.42		681.02	683.05	2.03	683.00	1.98	680.43	-0.59
0.468		682.05	683.68	1.63	683.62	1.57	681.15	-0.90
0.475		682.47	683.86	1.39	683.80	1.33	681.29	-1.18
0.49		682.81	684.02	1.21	683.97	1.16	681.33	-1.48
0.491		682.72	683.99	1.27	683.94	1.22	681.33	-1.39
0.495		682.71	684.00	1.29	683.94	1.23	681.35	-1.36
0.52		682.82	684.08	1.26	684.02	1.20	681.45	-1.37
0.63		683.00	684.36	1.36	684.30	1.30	681.63	-1.37
0.635		681.82	684.25	2.43	684.19	2.37	681.61	-0.21
0.67		683.33	684.58	1.25	684.53	1.20	C	C
0.675		686.00	685.23	-0.77	685.20	-0.80	C	C
0.72		687.93	687.97	0.04	687.93	0.00	C	C
0.725		687.93	687.97	0.04	687.94	0.01	C	c
0.73		687.35	687.78	0.43	687.75	0.40	°C	^c
0.74	Downstream USH 45	688.72	688.66	-0.06	688.62	-0.10	C	C
0.76	Upstream USH 45	688.84	689.31	0.47	689.26	0.42	c	^C
0.8		689.94	690.21	0.27	690.17	0.23	689.15	-0.79
0.805		691.42	690.64	-0.78	690.58	-0.84	689.39	-2.03
0.81		692.97	691.97	-1.00	691.92	-1.05	690.77	-2.20
0.8125	Canadian Pacific Railway (bridge)			·				** *
0.815		694.95	694.60	-0.35	694.52	-0.43	692.53	-2.42
0.82	· · · · · · · · · · · · · · · · · · ·	695.92	695.12	-0.80	695.04	-0.88	693.76	-2.16
0.83		696.00	695.24	-0.76	695.16	-0.84	693.76	-2.24
0.94		695.88	695.68	-0.20	695.60	-0.28	694.60	-1.28
1.04		695.80	695.91	0.11	695.84	0.04	696.00	0.20
1.14		696.28	696.85	0.57	696.78	0.50	697.42	1.14
1.26		696.61	697.04	0.43	697.00	0.39	698.53	1.92
1.27	Downstream Mayfair Road	698.45	697.96	-0.49	697.91	-0.54	698.85	0.40
1.275	Upstream Mayfair Road	698.46	698.07	-0.39	698.02	-0.44	698.92	0.46
1.28		697.67	698.05	0.38	698.00	0.33	698.97	1.30
1.37		699.16	700.45	1.29	700.33	1.17	700.70	1.54
1.45		699.53	701.24	1.71	701.11	1.58	701.13	1.60
1.46		700.59	700.80	0.21	700.67	0.08	700.66	0.07

				Flood Stage Ele	vation (Feet abov	e NGVD 1929)	-	
Location (River Mile)	Description	10-Year Existing ^a	10-Year Alternative EE	Change in Stage (feet)	10-Year Alternative EP	Change in Stage (feet)	10-Year Alternative FP ^D	Change in Stage (feet)
1.461	Union Pacific Railroad	702.04	701.08	-0.96	700.95	-1.09	701.07	-0.97
1.462		702.34	703.03	0.69	702.88	0.54	703.01	0.67
1.47		705.40	704.60	-0.80	704.41	-0.99	704.58	-0.82
1.49	W. Watertown Plank Road	705.10	704.83	-0.27	704.64	-0.46	704.81	-0.29
1.53		705.84	706.02	0.18	705.86	0.02	706.01	0.17
1.535		705.08	705.50	0.42	705.32	0.24	705.41	0.33
1.59		706.43	707.45	1.02	707.32	0.89	707.50	1.07
1.595		706.70	707.39	0.69	707.25	0.55	707.44	0.74
1.62		707.29	707.81	0.52	707.70	0.41	707.84	0.55
1.63		707.17	708.00	0.83	707.90	0.73	708.01	0.84
1.635		707.61	707.59	-0.02	707.53	-0.08	707.58	-0.03
1.69		709.07	709.29	0.22	709.22	0.15	709.28	0.21
1.695		709.01	709.14	0.13	709.10	0.09	709.13	0.12
1.76		710.60	710.58	-0.02	710.53	-0.07	710.57	-0.03
1.79		710.80	710.78	-0.02	710.73	-0.07	710.77	-0.03
1.86		711.18	711.16	-0.02	711.11	-0.07	711.15	-0.03
1.87		710.62	710.96	0.34	710.70	0.08	710.70	0.08
1.8725	N. 115th Street (bridge)				·			·
1.875		717.67	714.42	-3.25	714.52	-3.15	714.77	-2.90
1.88		718.04	714.90	-3.14	715.11	-2.93	715.36	-2.68
1.97		718.16	715.59	-2.57	715.71	-2.45	715.94	-2.22
2.06		718.19	715.96	-2.23	716.03	-2.16	716.25	-1.94
2.15		718.26	716.41	-1.85	716.44	-1.82	716.60	-1.66
2.19		718.29	716.59	-1.70	716.61	-1.68	716.76	-1.53
2.21		718.43	716.68	-1.75	716.70	-1.73	716.85	-1.58
2.24		718.38	716.78	-1.60	716.78	-1.60	716.92	-1.46
2.34		718.85	717.00	-1.85	716.99	-1.86	717.13	-1.72
2.42		718.99	717.03	-1.96	717.02	-1.97	717.16	-1.83
2.5		718.94	717.46	-1.48	717.41	-1.53	717.50	-1.44

50-YEAR RECURRENCE INTERVAL

			н. -	Flood Stage Ele	vation (Feet abov	 we NGVD 1929)		
Location (River Mile)	Description	50-Year Existing ^a	50-Year Alternative EE	Change in Stage (feet)	50-Year Alternative EP	Change in Stage (feet)	50-Year Alternative FP ^b	Change in Stage (feet)
0.06		676.80	679.66	2.86	679.56	2.76	679.69	2.89
0.11		677.04	679.93	2.89	679.83	2.79	680.00	2.96
0.22		677.84	680.68	2.84	680.57	2.73	680.59	2.75
0.225		678.77	680.29	1.52	680.18	1.41	680.57	1.80
0.23		679.69	680.05	0.36	679.96	0.27	680.66	0.97
0.33		682.44	683.45	1.01	683.35	0.91	681.55	-0.89
0.42		682.98	684.64	1.66	684.54	1.56	682.40	-0.58
0.468		684.07	685.39	1.32	685.29	1.22	683.20	-0.87
0.475		684.54	685.61	1.07	685.50	0.96	683.36	-1.18
0.49		684.88	685.77	0.89	685.66	0.78	683.40	-1.48
0.491		684.81	685.74	0.93	685.63	0.82	683.40	-1.41
0.495		684.83	685.74	0.91	685.63	0.80	683.42	-1.41
0.52		684.91	685.82	0.91	685.71	0.80	683.52	1.39
0.63		684.98	686.07	1.09	685.96	0.98	683.69	-1.29
0.635		683.98	685.97	1.99	685.86	1.88	683.67	-0.31
0.67		684.97	686.23	1.26	686.13	1.16	C	C
0.675		687.36	686.03	-1.33	685.99	-1.37	C	C
0.72		689.38	689.10	-0.28	689.02	-0.36	^C	C
0.725		689.38	689.11	-0.27	689.02	-0.36	C	<u> </u>
0.73		688.84	688.55	-0.29	688.50	-0.34	C	C
0.74	Downstream USH 45	690.36	689.98	-0.38	689.90	-0.46	C	c
0.76	Upstream USH 45	690.46	690.68	0.22	690.60	0.14	c	C

1				Flood Stage Ele	vation (Feet abov	e NGVD 1929)	·····	
Location (River Mile)	Description	50-Year Existing ^a	50-Year Alternative EE	Change in Stage (feet)	50-Year Alternative EP	Change in Stage (feet)	50-Year Alternative FP ^b	Change in Stage (feet)
0.8		691.73	691.76	0.03	691.67	-0.06	690.88	-0.85
0.805		692.81	692.05	-0.76	691.85	-0.96	690.56	-2.25
0.81		694.41	693.21	-1.20	693.06	-1.35	692.04	-2.37
0.8125	Canadian Pacific Railway (bridge)							·
0.815		698.42	697.65	-0.77	697.37	-1.05	694.61	-3.81
0.82		699.15	697.95	-1.20	697.68	-1.47	695.60	-3.55
0.83		699.24	698.03	-1.21	697.77	-1.47	695.61	-3.63
0.94		699.19	698.32	-0.87	698.05	-1.14	696.25	-2.94
1.04		699.04	698.38	-0.66	698.13	-0.91	697.36	-1.68
1.14		699.30	698.90	-0.40	698.67	-0.63	698.84	-0.46
1.26		699.07	698.54	-0.53	698.34	-0.73	699.85	0.78
1.27	Downstream Mayfair Road	700.40	699.45	-0.95	699.31	-1.09	700.24	-0.16
1.275	Upstream Mayfair Road	700.41	699.57	-0.84	699.42	-0.99	700.31	-0.10
1.28		699.81	699.51	-0.30	699.37	-0.44	700.35	0.54
1.37		700.71	701.83	1.12	701.59	0.88	702.18	1.47
1.45		701.04	702.61	1.57	702.37	1.33	702.58	1.54
1.46		701.84	702.13	0.29	701.90	0.06	702.11	0.27
1.461	Union Pacific Railroad	703.61	702.47	-1.14	702.18	-1.43	702.35	-1.26
1.462		703.91	704.63	0.72	704.32	0.41	704.50	0.59
1.47		707.83	706.69	-1.14	706.28	-1.55	706.52	-1.31
1.49	W. Watertown Plank Road	707.66	706.86	-0.80	706.46	-1.20	706.69	-0.97
1.53		708.03	707.81	-0.22	707.46	-0.57	707.66	-0.37
1.535		707.34	707.44	0.10	707.06	-0.28	707.24	-0.10
1.59		707.69	709.00	1.31	708.68	0.99	708.90	1.21
1.595		708.07	708.97	0.90	708.65	0.58	708.87	0.80
1.62		708.64	709.17	0.53	708.88	0.24	709.08	0.44
1.63		708.49	709.31	0.82	709.03	0.54	709.21	0.72
1.635		708.74	709.12	0.38	708.80	0.06	709.01	0.27
1.69		710.28	709.97	-0.31	709.77	-0.51	709.89	-0.39
1.695		710.14	709.75	-0.39	709.44	-0.70	709.64	-0.50
1.76		711.82	711.00	-0.82	710.96	-0.86	710.97	-0.85
1.79		712.01	711.23	-0.78	711.18	-0.83	711.19	-0.82
1.86		712.39	711.53	-0.86	711.48	-0.91	711.51	-0.88
1.87		711.33	711.00	-0.33	710.63	-0.70	710.75	-0.58
1.8725	N. 115th Street (bridge)					· • •	¹²	
1.875		717.80	717.72	-0.08	717.66	-0.14	718.28	0.48
1.88		718.51	718.28	-0.23	718.30	-0.21	718.91	0.40
1.97		7.18.69	718.66	-0.03	718.64	-0.05	719.21	0.52
2.06		718.72	718.84	0.12	718.80	0.08	719.34	0.62
2.15		718.83	719.10	0.27	719.03	0.20	719.54	0.71
2.19		718.87	719.20	0.33	719.12	0.25	719.62	0.75
2.21		719.14	719.27	0.13	719.19	0.05	719.68	0.54
2.24		719.05	719.32	0.27	719.23	0.18	719.71	0.66
2.34	· ·	719.80	719.46	-0.34	719.36	-0.44	719.83	0.03
2.42		719.97	719.48	-0.49	719.38	-0.59	719.84	-0.13
2.5		719.85	719.53	-0.32	719.42	-0.43	719.86	0.01

100-YEAR RECURRENCE INTERVAL

		· *						
Location (River Mile)	Description	100-Year Existing ^a	100-Year Alternative EE	Change in Stage (feet)	100-Year Alternative EP	Change in Stage (feet)	100-Year Alternative FP ^b	Change in Stage (feet)
0.06		677.30	680.24	2.94	680.10	2.80	680.33	3.03
0.11		677.52	680.50	2.98	680.36	2.84	680.64	3.12
0.22		678.32	681.24	2.92	681.11	2.79	681.25	2.93
0.225		679.26	680.86	1.60	680.72	1.46	681.23	1.97
0.23	and the second	680.29	680.57	0.28	680.44	0.15	681.34	1.05

				Flood Stage Ele	vation (Feet abov	e NGVD 1929)		
1		100 Year	100-Vear	Change in	100-Year	Change in	100-Year	Change in
(River Mile)	Description	Existing ^a	Alternative EE	Stage (feet)	Alternative EP	Stage (feet)	Alternative FP ^b	Stage (feet)
0.33		682.97	683.98	1.01	683.87	0.90	682.26	-0.71
0.42		683.48	685.18	1.70	685.07	1.59	683.11	-0.37
0.468		684.69	685.99	1.30	685.87	1.18	683.94	-0.75
0.475		685.20	686.22	1.02	686.09	0.89	684.10	-1.10
0.49		685.54	686.37	0.83	686.25	0.71	684.14	-1.40
0.491		685.48	686.35	0.87	686.22	0.74	684.14	-1.34
0.495		685.51	686.35	0.84	686.22	0.71	684.16	-1.35
0.52		685.59	686.43	0.84	686.30	0.71	684.26	-1.33
0.63		685.62	686.67	1.05	686.55	0.93	684.43	-1.19
0.635		684.63	686.58	1.95	686.45	1.82	684.40	-0.23
0.67		685.63	686.82	1.19	686.70	1.07	c,d	c,d
0.675		687.81	686.56	-1.25	686.45	-1.36		
0.72		689.87	689.46	-0.41	689.38	-0.49	C,U	
0.725		689.87	689.46	-0.41	689.38	-0.49		,u
0.73		689.33	688.71	-0.62	688.68	-0.65	,u	c,d
0.74	Downstream USH 45	690.93	690.50	-0.43	690.38	-0.55	c.d	c.d
0.76	Upstream USH 45	691.02	691.20	0.18	691.08	0.06		
0.8		692.38	692.33	-0.05	692.23	-0.15	691.49	-0.89
0.805		693.32	692.59	-0.73	692.39	-0.93	690.98	-2.34
0.81		694.79	693.67	-1.12	693.49	-1.30	692.47	-2.32
0.8125	Canadian Pacific Railway (bridge)							
0.815		701.44	698.49	-2.95	698.12	-3.32	695.14	-6.30
0.82		701.60	698.82	-2.78	698.46	-3.14	696.13	-5.47
0.83		701.66	698.91	-2.75	698.56	-3.10	696.14	-5.52
0.94		701.62	699.18	-2.44	698.84	-2.78	690.76	-4.60
1.04		701.51	699.23	-2.28	698.89	-2.02	699.31	-3.03
1.14		701.68	699.68	-2.00	699.36	-2.32	700.39	-1.13
1.26		701.42	699.23	-2.19	698.95	-2.47	700.23	-1.152
1.27	Downstream Mayfair Road	702.24	700.08	-2.16	699.87	-2.37	700.72	-1.46
1.275	Upstream Mayfair Road	702.25	700.19	-2.06	609.97	-2.20	700.73	-1.06
1.28		701.88	700.13	-1.75	702.05	-0.20	702.67	0.42
1.37		702.25	702.35	0.10	702.03	0.39	702.07	0.64
1.45		702.42	703.11	0.89	702.81	0.07	702.58	0.31
1.46		702.27	702.62	0.35	702.54	-1.60	702.80	-1.42
1.461	Union Pacific Railroad	704.22	702.98	-1.24	702.02	0.32	705.02	0.51
1.462		704.51	705.21	-1.26	706.95	-1.77	707.22	-1.50
1.47	Mit Minterstressen Disate Dand	708.72	707.40	-1.20	707.11	-1.45	707.36	-1.20
1.49	w. watertown Plank Road	708.50	707.00	-0.39	708.03	-0.84	708.26	-0.61
1.53		708.87	708.46	-0.16	707.67	-0.63	707.88	-0.42
1.535		708.30	709.61	1.08	709.20	0.67	709.43	0.90
1.09		708.93	709.59	0.72	709.18	0.31	709.40	0.53
1.090	<u></u>	709.37	709.74	0.37	709.36	-0.01	709.57	0.20
1.02		709.22	709.87	0.65	709.49	0.27	709.69	0.47
1.03		709.13	709.72	0.59	709.32	0.19	709.54	0.41
1.60		710.70	710.39	-0.31	710.09	-0.61	710.24	-0.46
1.00		710.53	710.27	-0.26	709.92	-0.61	710.10	-0.43
1.76		712.23	711.18	-1.05	711.04	-1.19	711.10	-1.13
1.79		712.41	711.41	-1.00	711.27	-1.14	711.33	-1.08
1.86		712.79	711.65	-1.14	711.57	-1.22	711.60	-1.19
1.87		711.79	710.95	-0.84	710.99	-0.80	711.13	-0.66
1.8725	N. 115th Street (bridge)			·			· · · ·	••
1.875		719.87	719.21	-0.66	719.48	-0.39	720.21	0.34
1.88		720.58	719.80	-0.78	720.10	-0.48	720.82	0.24
1.97		720.67	720.08	-0.59	720.32	-0.35	721.00	0.33
2.06		720.66	720.21	-0.45	720.42	-0.24	721.09	0.43
2.15		720.72	720.41	-0.31	720.59	-0.13	721.22	0.50

			Flood Stage Elevation (Feet above NGVD 1929)							
Location (River Mile)	Description	100-Year Existing ^a	100-Year Alternative EE	Change in Stage (feet)	100-Year Alternative EP	Change in Stage (feet)	100-Year Alternative FP ^b	Change in Stage (feet)		
2.19		720.74	720.48	-0.26	720.64	-0.10	721.27	0.53		
2.21		720.97	720.54	-0.43	720.69	-0.28	721.32	0.35		
2.24		720.88	720.58	-0.30	720.72	-0.16	721.34	0.46		
2.34		721.51	720.69	-0.82	720.82	-0.69	721.43	-0.08		
2.42		721.61	720.70	-0.91	720.83	-0.78	721.43	-0.18		
2.5		721.49	720.68	-0.81	720.81	-0.68	721.41	-0.08		

^aPlanned year 2020 land use, existing channel conditions.

^bUnder Alternative Plan FP, a Manning's roughness coefficient of 0.06 was applied for the stream channel in the reach where the streambed would be lowered. That is consistent with the streambed lowering alternative that was analyzed under the District watercourse system plan. For Alternatives B, C, EE, and EP, a Manning's roughness coefficient of 0.04 was applied for the rehabilitated stream channel.

^CAdditional cross-sections were used to model the channel lowering in this reach. See Table 11 for flood stage elevations.

^dSee Figure 17 for a comparison of 100-year flood profiles.

Source: SEWRPC.

flood stages at River Mile 2.21 would result in less overflow into the old Underwood Creek channel in comparison to existing channel conditions. Thus, the 100-year flood profile would be lowered along the old channel.

Cost of Alternative Plan EE

The total capital cost of Alternative Plan EE is estimated to be \$29,655,000 dollars. The annual operation and maintenance cost is estimated to be \$110,000. Assuming an annual interest rate of 6 percent and a project life and amortization period of 50 years, the average annual cost of the project is \$1,993,000.

Alternative Plan EP----Removal of Concrete Channel Lining, Expanded

Overbank Lowering along Underwood Creek, Overbank Lowering and Retention

Basin along the South Branch, Culvert Replacement or Modification, and Existing

Upstream Channel Conditions along Underwood Creek in Waukesha County

As shown on Map 5, the measures called for under Alternative Plan EP are the same as under Alternative Plan EE except that Alternative EP calls for the left overbank area along the South Branch of Underwood Creek south of the IH 94 crossing to be excavated to provide an additional 280 acre-feet of floodwater storage. The excavated retention basin would have a surface area of about 15 acres and would be about 20 feet deep. Floodwaters would enter the basin through flow over the left (west) bank of the South Branch. This basin would have a pumping station to enable pumping of floodwaters back into Underwood Creek between flood events.

Relative to existing channel conditions, the overall flood storage volume during a 100-year flood would be increased from 380 acre-feet to 417 acre-feet,¹⁴ or an increase of about 10 percent along Underwood Creek, and from 91 acre-feet to 420 acre-feet, or an increase of about 362 percent along the South Branch of Underwood Creek.

¹⁴The amount of floodwater storage along Underwood Creek would be less than under Alternative Plan EE because the provision of additional storage along the South Branch would reduce the extent of the downstream 100—year floodplain along Underwood Creek.



UNDERWOOD CREEK 100-YEAR RECURRENCE INTERVAL FLOOD PROFILES FOR PLANNED (2020) LAND USE CONDITIONS EXISTING CHANNEL CONDITIONS AND ALTERNATIVE EE: REMOVAL OF CONCRETE CHANNEL LINING, EXPANDED OVERBANK LOWERING ALONG UNDERWOOD CREEK, OVERBANK LOWERING ALONG THE SOUTH BRANCH, CULVERT REPLACEMENT OR MODIFICATION, AND EXISTING UPSTREAM CHANNEL CONDITIONS ALONG UNDERWOOD CREEK IN WAUKESHA COUNTY

Figure 12

Map 5

ALTERNATIVE EP REMOVAL OF CONCRETE CHANNEL LINING, EXPANDED OVERBANK LOWERING ALONG UNDERWOOD CREEK, OVERBANK LOWERING AND RETENTION BASIN ALONG THE SOUTH BRANCH OF UNDERWOOD CREEK, CULVERT REPLACEMENT OR MODIFICATION, AND EXISTING UPSTREAM CHANNEL CONDITIONS ALONG UNDERWOOD CREEK IN WAUKESHA COUNTY







Map 5 (continued)

	LEGEND
1.62	DISTANCE FROM MOUTH IN RIVER MILES
<u>→ ^{54"} (</u>	EXISTING CULVERT AND SIZE
	CULVERT REPLACEMENT OR MODIFICATION
	PRIMARY ENVIRONMENTAL CORRIDOR BOUNDARY
_	WETLAND BOUNDARY
	PROPOSED OVERBANK LOWERING AREA
	PROPOSED RETENTION BASIN
	PROPOSED PUMP STATION
RCP	REINFORCED CONCRETE PIPE
CMP	CORRUGATED METAL PIPE
NOTE	: Plan calls for removal of existing concrete channel

NOTE: Plan calls for removal of existing concrete channel lining along Underwood Creek from River Mile 0.00 to River Mile 2.54.



Source: SEWRPC.

Underwood Creek flood flows and stages with this alternative implemented are set forth in Tables 8 and 9, respectively. A comparison of the changes in flood stages relative to planned land use, existing channel conditions is given in Table 7. A comparison of typical existing and proposed channel and overbank cross-sections in each reach is shown on Figures 9 through 11.

Streambank and Streambed Protection

Along about 0.81 mile, or 32 percent of the 2.54-mile-long reach of Underwood Creek, it was found that average channel streamflow velocities could exceed six feet per second, with some being as great 16 feet per second under this alternative. Bank and bed stabilization, perhaps through a combination of bio-engineering and riprap or gabion protection, would be required in some reaches of high erosion potential.

There are several locations where flow velocities would approach or exceed 10 feet per second during floods with recurrence intervals ranging from two through 100 years. Those locations include the N. 115th Street culverts and the bridges at Watertown Plank Road, the Union Pacific Railway, the Canadian Pacific Railway, and USH 45. Special erosion control treatment, perhaps involving "hard" armoring solutions are likely to be required at those locations.

Effects of Implementation of the Alternative Plan

As seen from Table 7 and Figure 13, the implementation of this alternative would increase 100-year recurrence interval flood stages by between 0.2 and 2.8 feet in the potential damage reach along Fisher Parkway between the mouth and River Mile 0.67. That reach includes the Fisher Parkway area, two commercial properties, and the Serafino Square apartments. Under Alternative EP, in addition to portions of Fisher Parkway and N. 104th Street which would be expected to be flooded during a 100-year flood occurring under existing channel conditions, the church building near River Mile 0.23, the lower level of the southeastern apartment building in the Serafino Square complex, small portions of N. 102nd and N. 106th Streets, and 11 houses and 30 garages may also be flooded. Thus, even with the mitigative overbank lowering and retention storage measures, this alternative plan would have negative street and structural flooding impacts.

In general, in the 1.8-mile-long reach from USH 45 upstream to the Milwaukee-Waukesha county line, 100-year flood stages would be reduced by as much as three feet in comparison to existing channel conditions. However, there would still be some stage increases in the vicinity of the Union Pacific Railroad and W. Watertown Plank Road. No flooding of streets or buildings would be caused by those stage increases. Reduced 100-year flood stages at River Mile 2.21 would result in less overflow into the old Underwood Creek channel in comparison to existing channel conditions. Thus, the 100-year flood profile would be lowered along the old channel.

Cost of Alternative Plan EP

The total capital cost of Alternative Plan EP is estimated to be \$34,495,000 dollars. The annual operation and maintenance cost is estimated to be \$110,000. Assuming an annual interest rate of 6 percent and a project life and amortization period of 50 years, the average annual cost of the project is \$2,300,000.

Alternative Plan FP—Removal of Concrete Channel Lining, Streambed Lowering

and Expanded Overbank Lowering along Underwood Creek, Overbank Lowering and

Retention Basin along the South Branch, Culvert Replacement or Modification, and

Existing Upstream Channel Conditions along Underwood Creek in Waukesha County

As shown on Map 6, in addition to the measures called for under Alternative Plan EP, this alternative calls for streambed lowering along Underwood Creek between River Mile 0.22 and 1.45 and construction of a reinforced concrete floodwall with associated interior drainage facilities.

The streambed would be lowered by as much as 3.9 feet in this reach and four existing two to four-foot high channel drop structures would be removed. Some of these might be replaced with a series of lower (approximately one foot-high), more natural structures. The streambed lowering is intended to eliminate 100-year flood stage increases in the potential structure damage reach along Fisher Parkway. Under Alternative Plan FP,

UNDERWOOD CREEK FLOOD FLOWS—EXISTING (1995) AND PLANNED (2020) LAND USE CONDITIONS WITH CONCRETE LINING REMOVED, MAXIMUM EXPANDED CHANNEL CROSS-SECTION IN WAUWATOSA AND PUMP-OUT STORAGE ALONG SOUTH BRANCH OF UNDERWOOD CREEK (ALTERNATIVE EP)

		Recurrence Interval							
		Two	Year	10-Year		50-Year		100-Year	
Location (River Miles)	Description	1995 Land Use (cfs)	2020 Land Use (cfs)						
0.00	Confluence with Menomonee River	2,080	2,130	3,730	3,780	5,060	5,100	5,580	5,630
0.76	Upstream side of USH 45	2,070	2,110	3,760	3,820	5,160	5,210	5,720	5,770
1.26	About 590 feet down- stream of Mayfair Road	1,820	1,850	3,210	3,250	4,310	4,340	4,750	4,760
1.53	Upstream side of W. Watertown Plank Road	1,660	1,700	2,870	2,910	3,780	3,810	4,130	4,150
1.62 ^a	Just upstream of location where flow from old channel returns to Underwood Creek	b	1,680	b	2,810	b	3,660	bb	3,970
2.21 ^a	Just upstream of location where some flow in Underwood Creek is diverted to old channel	1,660	1,700	2,870	2,910	3,780	3,810	4,130	4,150
2.5	Just downstream from confluence with the South Branch of Underwood Creek	1,480	1,510	2,480	2,520	3,210	3,230	3,470	3,490

^aBetween River Miles 1.62 and 2.21, some flow leaves the main stem of Underwood Creek and enters the old stream channel. The flows at those river mile locations reflect that diversion.

^bNot specifically determined. Requires computation of flood profiles. These flows would be similar to those for 2020 land use conditions.

Source: SEWRPC.

overbank lowering in the wooded primary environmental corridor east of the channel and between River Mile 0.83 to 1.26 would be eliminated, since disturbance of that corridor would significantly alter a significant natural resource feature. A comparison of typical existing and proposed channel and overbank cross-sections in each reach is shown on Figures 14 through 16.

Relative to existing channel conditions, the overall flood storage volume during a 100-year flood would be increased from 380 acre-feet to 431 acre-feet, or an increase of about 13 percent along Underwood Creek, and from 91 acre-feet to 445 acre-feet, or an increase of about 389 percent along the South Branch of Underwood Creek.

Underwood Creek flood flows and stages with Alternative Plan FP implemented are set forth in Tables 10 and 11, respectively. A comparison of the changes in flood stages relative to planned land use, existing channel conditions is given in Table 7.

UNDERWOOD CREEK FLOOD STAGES: PROPOSED ALTERNATIVE EP CHANNEL WITH PLANNED YEAR 2020 LAND USE CONDITIONS^a

Location		Flood Stage Elevation (feet above NGVD 1929)						
(River Mile)	Description	Two-Year	10-Year	50-Year	100-Year			
0.06		675.49	678.06	679.56	680.10			
0.11		675.79	678.35	679.83	680.36			
0.22		676.50	679.08	680.57	681 11			
0.225		676.06	678.69	680.18	680.72			
0.23		676.25	678.61	679.96	680.44			
0.33		679.11	681.81	683 35	683.87			
0.42		680.22	683.00	684 54	685.07			
0.468		680.75	683.62	685 29	685.87			
0.475		680.88	683.80	685 50	686.09			
0.49		681.02	683.97	685.66	686.25			
0.491		680.99	683.94	685.63	686.22			
0.495		680.99	683.94	685.63	686.22			
0.52		681.10	684.02	685 71	686.30			
0.63		681.49	684.30	685.96	686 55			
0.635		681.36	684 19	685.86	686.45			
0.67		681.99	684.53	686 13	686 70			
0.675		683.77	685.20	685.99	686.45			
0.72		686.26	687.93	689.02	689.38			
0.725		686.26	687.94	689.02	689.38			
0.73		686.35	687.75	688 50	688.68			
0.74	Downstream USH 45	686.77	688.62	689 90	690.38			
0.76	Upstream USH 45	687.21	689.26	690.60	691.08			
0.8		687.82	690.17	691.67	692.23			
0.805		688.99	690.58	691.85	692.20			
0.81	· · · · · · · · · · · · · · · · · · ·	690.19	691.92	693.06	693.49			
0.8125	Canadian Pacific Railway (bridge)							
0.815		691.81	694.52	697.37	698.12			
0.82		692.40	695.04	697.68	698.46			
0.83	· · · ·	692.56	695.16	697.77	698.56			
0.94		693.16	695.60	698.05	698.84			
1.04		693.88	695.84	698.13	698.89			
1.14		695.06	696.78	698.67	699.36			
1.26		695.92	697.00	698.34	698.95			
1.27	Downstream Mayfair Road	696.36	697.91	699.31	699.87			
1.275	Upstream Mayfair Road	696.44	698.02	699.42	699.97			
1.28		696.46	698.00	699.37	699.92			
1.37		698.23	700.33	701.59	702.05			
1.45		698.91	701.11	702.37	702.81			
1.46		698.41	700.67	701.90	702.34			
1.461	Union Pacific Railroad	699.09	700.95	702.18	702.62			
1.462		700.65	702.88	704.32	704.83			
1.47		701.58	704.41	706.28	706.95			
1.49	W. Watertown Plank Road	701.90	704.64	706.46	707.11			
1.53		703.55	705.86	707.46	708.03			
1.535		702.88	705.32	707.06	707.67			
1.59		705.62	707.32	708.68	709.20			
1.595		705.60	707.25	708.65	709.18			
1.62		706.02	707.70	708.88	709.36			
1.63		706.19	707.90	709.03	709.49			
<u>1.63</u> 5		705.55	707.53	708.80	709.32			

Location		Flood Stage Elevation (feet above NGVD 1929)						
(River Mile)	Description	Two-Year	10-Year	50-Year	100-Year			
1.69		708.21	709.22	709.77	710.09			
1.695		707.79	709.10	709.44	709.92			
1.76		709.62	710.53	710.96	711.04			
1.79		709.84	710.73	711.18	711.27			
1.86		710.30	711.11	711.48	711.57			
1.87		710.20	710.70	710.63	710.99			
1.8725	N. 115th Street (bridge)							
1.875		711.21	714.52	717.66	719.48			
1.88		711.58	715.11	718.30	720.10			
1.97		712.70	715.71	718.64	720.32			
2.06		713.34	716.03	718.80	720.42			
2.15		713.93	716.44	719.03	720.59			
2.19		714.19	716.61	. 719.12	720.64			
2.21		714.29	716.70	719.19	720.69			
2.24		714.44	716.78	719.23	720.72			
2.34		714.79	716.99	719.36	720.82			
2.42		714.90	717.02	719.38	720.83			
2.5		715.59	717.41	719.42	720.81			

^aConcrete lining removed in Wauwatosa, expanded channel cross-section in Wauwatosa along Underwood Creek, pump-out storage along the South Branch, and existing channel upstream of Wauwatosa.

Source: SEWRPC.

Streambank and Streambed Protection

Along about 0.72 mile, or 28 percent of the 2.54-mile-long reach of Underwood Creek, it was found that average channel streamflow velocities could exceed six feet per second, with some being as great 16 feet per second under this alternative. Bank and bed stabilization, perhaps through a combination of bio-engineering and riprap or gabion protection, would be required in some reaches of high erosion potential.

There are several locations where flow velocities would approach or exceed 10 feet per second during floods with recurrence intervals ranging from two through 100 years. Those locations include the N. 115th Street culverts and the bridges at Watertown Plank Road, the Union Pacific Railway, the Canadian Pacific Railway, and USH 45. Special erosion control treatment, perhaps involving "hard" armoring solutions are likely to be required at those locations.

Effects of Implementation of the Alternative Plan

As seen from Table 7 and Figure 17, the implementation of this alternative would increase 100-year recurrence interval flood stages from one to three feet in the reach extending from the mouth of Underwood Creek to River Mile 0.23. That reach includes the Serafino Square Apartments. A one- to four-foot-high, 460-foot-long floodwall would be required to protect the apartment building at the southeastern corner of that complex during floods with recurrence intervals through 100 years. Appropriate interior drainage facilities would be required to manage local stormwater runoff from the area on the landward side of the floodwall.

Implementation of the alternative would reduce 100-year recurrence interval flood stages by between 0.2 and 1.4 feet in the potential damage reach along Fisher Parkway from River Mile 0.33 through River Mile 0.635. Under Alternative FP, portions of Fisher Parkway and N. 104th Street would be expected to be flooded during a 100-year flood, similar to the situation under existing channel conditions. However, none of the buildings flooded under Alternative Plans A, B, C, EE, and EP would be expected to be flooded.





Scale: 1 Inch Horizontal = 0.2 Miles 1 Inch Vertical = 10 Feet

Source: SEWRPC.

Map 6

ALTERNATIVE FP

REMOVAL OF CONCRETE CHANNEL LINING, STREAMBED LOWERING AND EXPANDED OVERBANK LOWERING ALONG UNDERWOOD CREEK, OVERBANK LOWERING AND RETENTION BASIN ALONG THE SOUTH BRANCH OF UNDERWOOD CREEK, CULVERT REPLACEMENT OR MODIFICATION, AND EXISTING UPSTREAM CHANNEL CONDITIONS ALONG UNDERWOOD CREEK IN WAUKESHA COUNTY

LEGEND

- 0.11 DISTANCE FROM MOUTH IN RIVER MILES
- PRIMARY ENVIRONMENTAL CORRIDOR BOUNDARY
- WETLAND BOUNDARY
- PROPOSED OVERBANK LOWERING AREA
- PROPOSED STREAMBED LOWERING
- PROPOSED FLOODWALL

Source: SEWRPC.

NOTE: Plan calls for removal of existing concrete channel lining along Underwood Creek from River Mile 0.00 to River Mile 2.54.

GRAPHIC SCALE

350

700 FEET



53



LEGEND

- 1.62 DISTANCE FROM MOUTH IN RIVER MILES
-) 54" EXISTING CULVERT AND SIZE
- CULVERT REPLACEMENT OR MODIFICATION
- PRIMARY ENVIRONMENTAL CORRIDOR BOUNDARY
- WETLAND BOUNDARY
- PROPOSED OVERBANK LOWERING AREA
- PROPOSED RETENTION BASIN
- PROPOSED PUMP STATION
- RCP REINFORCED CONCRETE PIPE
- CMP CORRUGATED METAL PIPE

NOTE: Plan calls for removal of existing concrete channel lining along Underwood Creek from River Mile 0.00 to River Mile 2.54.

Source: SEWRPC.

MMSD UNDERWOOD CREEK CONCRETE REMOVAL STUDY UNDERWOOD CREEK RIVER MILE 0.33-COMPARISON OF EXISTING AND ALTERNATIVE FP CHANNEL CONDITIONS

Figure 14

NOTE: This exhibit shows the main changes to the channel and overbank. The stream channel would be rehabilitated to include pool, riffle, and run sequences in a meandering low flow channel along with substrate enhancement and appropriate vegetation.

Source: SEWRPC.

Source: SEWRPC.

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UNDERWOOD CREEK FLOOD FLOWS-EXISTING (1995) AND PLANNED (2020) LAND USE CONDITIONS WITH CONCRETE LINING REMOVED, EXPANDED CHANNEL CROSS-SECTIONS, PUMP-OUT STORAGE ALONG SOUTH BRANCH OF UNDERWOOD CREEK, AND PROPOSED STREAMBED LOWERING (ALTERNATIVE FP)

			Recurrence Interval						
		Two-Year		10-Year		50-Year		100-Year	
Location (River Miles)	Description	1995 Land Use (cfs)	2020 Land Use (cfs)						
0.00	Confluence with Menomonee River	2,070	2,110	3,750	3,810	5,130	5,170	5,670	5,710
0.76	Upstream side of USH 45	2,060	2,110	3,800	3,860	5,260	5,320	5,850	5,900
1.26	About 590 feet down- stream of Mayfair Road	1,880	1,910	3,350	3,380	4,510	4,540	4,980	4,990
1.53	Upstream side of W. Watertown Plank Road	1,700	1,730	2,950	2,990	3,900	3,930	4,270	4,280
1.62 ^a	Just upstream of location where flow from old channel returns to Underwood Creek	b	1,710	b	2,890	b	3,770	b	4,090
2.21 ^a	Just upstream of location where some flow in Underwood Creek is diverted to old channel	1,700	1,730	2,950	2,990	3,900	3,930	4,270	4,280
2.5	Just downstream from confluence with the South Branch of Underwood Creek	1,480	1,510	2,490	2,520	3,210	3,230	3,470	3,490

^aBetween River Miles 1.62 and 2.21, some flow leaves the main stem of Underwood Creek and enters the old stream channel. The flows at those river mile locations reflect that diversion.

^bNot specifically determined. Requires computation of flood profiles. These flows would be similar to those for 2020 land use conditions.

Source: SEWRPC.

In general, in the 1.8-mile-long reach from USH 45 upstream to the Milwaukee-Waukesha county line, 100-year flood stages would be reduced by as much as six feet in comparison to existing channel conditions. However, there would still be some stage increases in the vicinity of W. Mayfair Road, the Union Pacific Railroad, and upstream of 115th Street. No flooding of streets or buildings would be caused by those stage increases. The 100-year flood profile would be lowered along the old Underwood Creek channel.

Alternative Plan FP is the only plan that meets the criterion of not increasing the potential flood hazard to structures along Underwood Creek. However, implementation of that plan would be expected to increase the frequency of flooding of Hansen golf course and flood easements would be required from all property owners along the stream reaches where 100-year flood stages would increase under alternative plan channel conditions relative to existing channel conditions. As indicated by the stage comparisons in Table 7, flood easements would be required along about 0.9 mile of stream. Stage increases would be expected along lands owned by Milwaukee County, the Canadian Pacific Railway, and several other private owners.

UNDERWOOD CREEK FLOOD STAGES: PROPOSED ALTERNATIVE FP CHANNEL WITH PLANNED YEAR 2020 LAND USE CONDITIONS^a

Location		Flood Stage Elevation (feet above NGVD 1929)						
(River Mile)	Description	Two-Year	10-Year	50-Year	100-Year			
0.06		674.88	677.94	679.69	680.33			
0.11		675.17	678.24	680.00	680.64			
0.22		675.64	678.78	680.59	681.25			
0.225		675.62	678.75	680.57	681.23			
0.23		675.69	678.83	680.66	681.34			
0.33		676.47	679.60	681.55	682.26			
0.42		677.29	680.43	682.40	683.11			
0.468		677.90	681.15	683.20	683.94			
0.475		678.02	681.29	683.36	684 10			
0.49		678.08	681.33	683.40	684 14			
0.491		678.08	681.33	683.40	684 14			
0.495	· · · · · · · · · · · · · · · · · · ·	678.09	681 35	683.42	684.16			
0.52		678.19	681.45	683 52	684.26			
0.63		678.42	681.63	683.69	684.43			
0.635		678.41	681.61	683.67	684.40			
0.647		678.50	681.67	683 72	684.45			
0.652		678.47	681.65	683.71	694.43			
0.663		678 59	691.72	693.77	694.50			
0.668		678.59	691.60	692.75	694.30			
0.68		679.91	691.71	692 72	694.40			
0.685		670.01	691.70	692 71	694.44			
0.003		670.04	691.70	693.60	604.43			
0.037		679.99	601.75	603.00	084.29			
0.702		680.09	081.51	083.49	684.20			
0.714		681.49	683.19	684.39	684.95			
0.713		681.31	683.05	084.20	684.84			
0.73		082.04	084.34	085.82	686.35			
0.735		683.24	685.92	687.67	688.29			
0.747	Downstream USH 45	684.26	686.92	688.66	689.28			
0.752		684.26	686.99	688.76	689.39			
0.764	Upstream USH 45	685.61	688.24	689.98	690.58			
0.769		685.70	688.45	690.30	690.95			
0.781		686.13	688.78	690.62	691.26			
0.780		686.11	688.79	690.62	691.26			
0.797		686.87	689.23	690.94	691.55			
0.8		686.69	689.15	690.88	691.49			
0.805		687.58	689.39	690.56	690.98			
0.81		688.63	690.77	692.04	692.47			
0.8125	Canadian Pacific Railway (bridge)							
0.815		690.40	692.53	694.61	695.14			
0.82		691.40	693.76	695.60	696.13			
0.83		691.41	693.76	695.61	696.14			
0.94		692.53	694.60	696.25	696.76			
1.04	+	693.91	696.00	697.36	697.82			
1.14		695.10	697.42	698.84	699.31			
1.26		696.33	698.53	699.85	700.29			
1.2/	Downstream Mayfair Road	696.55	698.85	700.24	700.72			
1.275	Upstream Mayfair Road	696.61	698.92	700.31	700.79			
1.28		696.68	698.97	700.35	700.82			
1.3/	· · · · · · · · · · · · · · · · · · ·	698.13	700.70	702.18	702.67			
1.45		698.56	<u>701.13</u>	702.58	703.06			

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Location		Flood Stage Elevation (feet above NGVD 1929)					
(River Mile)	Description	Two-Year	10-Year	50-Year	100-Year		
1.46		698.17	700.66	702.11	702.58		
1.461	Union Pacific Railroad	699.14	701.07	702.35	702.80		
1.462		700.71	703.01	704.50	705.02		
1.47		701.66	704.58	706.52	707.22		
1.49	W. Watertown Plank Road	701.98	704.81	706.69	707.36		
1.53		703.61	706.01	707.66	708.26		
1.535	· · · · · · · · · · · · · · · · · · ·	703.05	705.41	707.24	707.88		
1.59		705.75	707.50	708.90	709.43		
1.595		705.72	707.44	708.87	709.40		
1.62		706.14	707.84	709.08	709.57		
1.63		706.27	708.01	709.21	709.69		
1.635		705.59	707.58	709.01	709.54		
1.69		708.26	709.28	709.89	710.24		
1.695		707.83	709.13	709.64	710.10		
1.76		709.65	710.57	710.97	711. <u>10</u>		
1.79		709.88	710.77	711.19	711.33		
1.86		710.33	711.15	711.51	711.60		
1.87		710.22	710.70	710.75	711.13		
1.8725	N. 115th Street (bridge)						
1.875		711.29	714.77	718.28	720.21		
1.88		711.66	715.36	718.91	720.82		
1.97		712.77	<u>715.94</u>	719.21	721.00		
2.06		713.40	716.25	719.34	721.09		
2.15		713.94	716.60	719.54	721.22		
2.19		714.20	716.76	719.62	721.27		
2.21		714.30	<u>716.85</u>	719. <u>68</u>	721.32		
2.24		714.43	716.92	719.71	721.34		
2.34		714.78	717.13	719.83	721.43		
2.42		714.90	717.16	719.84	721.43		
2.5		715.59	717.50	71 <u>9.8</u> 6	721.41		

^aConcrete lining removed in Wauwatosa, expanded channel cross-section in Wauwatosa, pump-out storage along the South Branch, streambed lowering downstream of River Mile 1.45, and existing channel upstream of Wauwatosa.

Source: SEWRPC.

Cost of Alternative Plan FP

The total capital cost of Alternative Plan FP is estimated to be \$34,080,000 dollars. The annual operation and maintenance cost is estimated to be \$75,000. Assuming an annual interest rate of 6 percent and a project life and amortization period of 50 years, the average annual cost of the project is \$2,239,000.

EVALUATION OF THE ALTERNATIVE PLANS

Each of the alternative plans would achieve the objective of removing the concrete lining in Underwood Creek; however, only alternative Plan FP would satisfy the criterion that there be no increase in the flood hazard to structures along Underwood Creek. That criterion is considered an absolute standard that must be met for successful implementation of the project. Chapter NR 116 of the *Wisconsin Administrative Code* allows activities that would increase 100-year flood stages by 0.01 foot or more if appropriate legal arrangements are made with all affected property owners and municipalities. However, the anticipated increases in the 100-year flood stage under Alternative Plans B, C, EE, and EP would result in flooding of a church, an apartment building, 11 houses and 30 garages. That level of flooding is obviously unacceptable and it makes those alternatives unsatisfactory.

Scale: 1 Inch Horizontal = 0.2 Miles 1 Inch Vertical = 10 Feet

Source: SEWRPC.

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Figure 17

Purchasing all of the potentially flooded properties is considered impractical given the objectives of the project. Thus, Alternative Plan FP - Removal of Concrete Channel Lining, Streambed Lowering and Expanded Overbank Lowering along Underwood Creek, Overbank Lowering and Retention Basin along the South Branch, Culvert Replacement or Modification, and Existing Upstream Channel Conditions along Underwood Creek in Waukesha County, is the only feasible alternative.

ADVANTAGES AND DISADVANTAGES OF ALTERNATIVE PLAN FP

Advantages

Implementation of this plan would enable rehabilitation of Underwood Creek in the 2.5-mile-long reach from the Milwaukee-Waukesha county line to the Menomonee River. That rehabilitation would help to promote fish migration along an additional 3.3 miles of the stream, extending from the downstream end of the Park and Shop stream enclosure in the Village of Elm Grove to the Menomonee River, and it would also improve aquatic and terrestrial habitat in the primary environmental corridor along the rehabilitated reach.

Disadvantages

The monetary cost of implementation of Alternative Plan FP would be very high. It is estimated that the capital cost would be \$34,080,000 and the average annual cost would be \$2,239,000, including \$75,000 in annual maintenance costs.

Implementation would result in periodic flooding of the athletic fields at Underwood Elementary School along Underwood Creek in the City of Wauwatosa and of the athletic fields and playground in Krueger Park along the South Branch of Underwood Creek in the City of Brookfield. Under existing channel conditions, those lands would not be expected to flood during the 100-year flood. With the plan implemented, those areas would flood during events with recurrence intervals greater than two years. Also, the currently undeveloped portion of Krueger Park, which would become the site of a retention basin under this alternative, would also be expected to be flooded during events with recurrence intervals greater than two years. Milwaukee County's Hansen golf course would be expected to flood more frequently also. Under existing channel conditions, significant flooding of the course would be expected to begin at about the 10-year flood. With the plan implemented, significant flooding of the golf course would be expected to begin during events with recurrence intervals greater flood. With the plan implemented, significant flooding of the course would be expected to begin at about the 10-year flood. With the plan implemented, significant flooding of the golf course would be expected to begin during events with recurrence intervals between two and 10 years.

Alternative Plan FP would satisfy the criterion that there be no increase in the flood hazard to structures along Underwood Creek; however, as noted above, there would still be some reaches where 100-year recurrence interval flood stages would be increased. Even though those increases would not cause increased flood hazard to structures, it is possible that City of Wauwatosa officials and residents may react negatively to any increase in flood stage, regardless of its impact.

Although, in general, overbank lowering sites were selected to avoid wetlands, sites along either side of the Creek upstream of River Mile 2.21 and along the South Branch are located in wetlands. This was done because the sites are logical candidates for the provision of floodwater storage, as identified under the District's watercourse system plan, and because it was desired to maximize the provision of storage to evaluate the feasibility of removal of the concrete lining. Wetland conditions could be restored at these sites following construction, but the wetlands would be disturbed during construction.

The provision of floodwater storage through overbank lowering in the reach upstream of N. 115th Street would entail the clearing of mature trees along the stream.

CONCLUDING STATEMENT

Alternative Plan FP is the only alternative which does not increase flood stages along Underwood Creek at critical locations. However, that alternative has certain disadvantages, including wetland impacts, potential conflicts with school grounds and park uses, and erosion control requirements. The information set forth in this report will
enable the District to evaluate that plan in the context of Districtwide flood control, stream rehabilitation, and operation and maintenance objectives.

If the District decides to proceed with implementation of Alternative Plan FP, it may be possible to refine the project to minimize wetland disturbance and also to adjust the streambed profile and channel cross section in the downstream reach where channel lowering is required.

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APPENDICES

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Appendix A

MENOMONEE RIVER WATERSHED WATERCOURSE SYSTEM PLAN GOALS, OBJECTIVES, STANDARDS, AND CRITERIA

MENOMONEE RIVER ALTERNATIVES CONCEPT DEVELOPMENT May 10, 1999 DRAFT

General Goals

- 1. Development of flood management (or flood damage reduction) alternatives which, to the extent practicable, will be effective in abating structural damage, and threats to public safety and health which are directly associated with rivers and streams for the one percent probability flood. The abatement of flooding or flood damage resulting from the inefficient or failed operation of local infrastructure (sanitary or storm sewers) is not directly included.
- 2. Is potentially permittable by federal, state, and local units of government;
- 3. Re-establish, to the extent possible, a sustainable river corridor and wetland ecosystem by restoring natural functions;
- 4. Where possible, enhance the biological, chemical, environmental and aesthetic resources of the river corridor and adjoining parkland; and
- 5. Do not increase public health risks and safety risks.

Defined Objectives

- Flow Regime. Evaluate changes in the flow regime ranging from low flow to 100-year flood flows. Maintain acceptable velocities for the full range of flows. Provide mitigation storage or acquire flood easements from affected property owners for any increases in flood stage.
- 2. <u>Groundwater Interaction</u>. Do not change existing groundwater levels without defining potential impacts and required mitigation.

- 3. <u>Aquatic and Terrestrial Ecosystems</u>. Restore, or where possible, enhance existing river habitat for aquatic and terrestrial species. Ensure passage for migrating fish (upstream and downstream). Restore existing corridor environment.
- 4. <u>Sediment Transport and Deposition</u>. Evaluate project impacts on sediment delivery and deposition. Incorporate design details to mitigate any significant negative impacts.
- 5. <u>Bioengineered Solution</u>. Avoid an artificial and "armored" solution and develop a flexible, soft, natural, bio-engineered solution where practical.
- 6. <u>Off-Site Impacts</u>. Minimize impacts to tributaries, surface drainage, and other watercourse connections to the river.
- 7. <u>Appearance</u>. Restore or enhance the existing appearance and aesthetic values.
- 8. <u>Access</u>. Maintain or enhance access for both human and wildlife uses following project implementation.
- 9. <u>Safety</u>. Provide a design that is safe for anglers, boaters, and the general public.
- 10. <u>Maintenance</u>. Provide a stable solution that requires minimal long-term maintenance and is somewhat self-healing.
- 11. <u>Construction Disturbance</u>. Select alternatives that are constructable without undue disturbance to resources, infrastructure, or people.
- 12. <u>Multiple Use</u>. Provide for multi-use opportunities (such as an environmental and recreational corridor) as a component of a larger flood control solution.

13. <u>Riparian Vegetation</u>. Restore the existing native vegetation characteristics in terms of hydrologic type (upland or lowland), character and diversity.

14. <u>Floodplain Land Use</u>. Following the purchase and removal of flood prone structures, and/or re-location of flood prone structures, vacated floodlands within a floodplain should not be allocated to any urban development except recreational or educational uses.

Standards or Criteria

Flow Regime

- 1. Maintain or enhance existing stream or river water depths ranging from low-flow to mean annual discharge.
- 2. Enhance stream or river flow conditions during lowand base-flow conditions.

Groundwater Interaction

1. Maintain or enhance groundwater, wetland and river interactions and relationships where important groundwater dependent natural resources exist.

Aquatic and Terrestrial Ecosystems

Aquatic Ecosystems

- 1. Enhance riverine and wetland habitat for aquatic and terrestrial species.
- 2. Enhance the ability of fish native to the Milwaukee River basin and Lake Michigan to migrate throughout the Menomonee River watershed.

Terrestrial Ecosystems

1. Enhance terrestrial habitats including woodlands, wildlife habitats, floodplain and other open space lands within the floodplain and environmental corridor.

Sediment Transport, Bioengineered Solution and Off-Site Impacts

- 1. Achieve river channel stability by enabling the river to develop a stable dimension, pattern and profile such that, over time, channel features are maintained and the stream system neither degrades nor aggrades to the extent that watershed influences permit.
- 2. Maintain frequency of pool, riffle and run sequences in the river channel
- 3. Enhance streambank stability.
- 4. Use natural streambank protection measures where feasible.
- 5. Minimize negative modifications and impacts to tributaries.

Appearance, Access & Safety

- 1. Maintain or enhance the existing aesthetics associated with the river and its corridor.
- 2. Minimize the use of practices that cause an increase in the height and steepness of stream banks, and other characteristics which otherwise limit safe access to or from the river.
- 3. Minimize the use of angular quarried stone along in areas, which are exposed above the water surface.
- 4. Minimize the use of practices which reduce the ability of wildlife populations to use the corridor as a travel lane and which reduce the ability of wildlife to migrate between aquatic and upland habitats (e.g. amphibians).

5. Maintain a neighborhood or community identity for the area.

Maintenance

- 1. Minimize the use of practices that require frequent, long-term and/or costly maintenance.
- 2. Minimize the need to modify infrastructure located beneath the existing river channel and adjoining river corridor, and protect as appropriate, when impacted.

Construction Disturbance

- 1. Minimize impacts during construction to residents, wildlife and water quality.
- 2. Minimize loss of use of the river and floodplain to people and fish/wildlife during re-establishment of vegetation.

Multiple Use

- 1. Enhance and expand passive and active use recreational parklands located within the floodplain and environmental corridor.
- 2. Enhance and expand public access and safety along the parklands, environmental corridor and floodplains.
- 3. Provide, were feasible, improved ecological diversity on publicly owned parklands and appropriate environmental education opportunities.

Riparian Vegetation

1. Restore, and where appropriate, enhance native vegetation and wildlife habitat diversity.

Floodplain Land Use

1. Land use within a floodplain should be recreational or educational

Source: Wisconsin Department of Natural Resources, Milwaukee County, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Appendix B

FLOOD FLOWS AND STAGES RELATIVE TO ALTERNATIVE PLANS A, B, AND C

Table B-1

UNDERWOOD CREEK FLOOD FLOWS-EXISTING CHANNEL WITH EXISTING (1995) AND PLANNED (2020) LAND USE CONDITIONS (FOR COMPARISON WITH APPENDIX B TABLES ONLY)^a

		Recurrence Interval (years)							
		Τv	vo	1	0	5	0	10	00
Location (River Mile)	Description	1995 Land Use (cfs)	2020 Land Use (cfs)	1995 Land Use (cfs)	2020 Land Use (cfs)	1995 Land Use (cfs)	2020 Land Use (cfs)	1995 Land Use (cfs)	2020 Land Use (cfs)
0.00	Confluence with Menomonee River	2,390	2,420	4,610	4,680	6,520	6,610	7,310	7,400
0.76	Upstream side of USH 45	2,350	2,370	4,510	4,570	6,350	6,430	7,110	7,190
1.26	About 590 feet down- stream of Mayfair Road	2,010	2,020	3,840	3,890	5,390	5,460	6,020	6,090
1.53	Upstream side of W. Watertown Plank Road	1,750	1,770	3,360	3,420	4,710	4,800	5,260	5,350
1.62 ^b	Just upstream of location where flow from old channel returns to Underwood Creek	1,750	1,770	3,250	3,300	4,560	4,650	5,080	5,160
2.21 ^b	Just upstream of location where some flow in Underwood Creek is diverted to old channel	1,750	1,770	3,360	3,420	4,710	4,800	5,260	5,350
2.5	Just downstream from confluence with the South Branch of Underwood Creek	1,360	1,390	2,620	2,690	3,690	3,790	4,120	4,230

^aThe specific results set forth in this appendix were refined during subsequent analyses, thus, they cannot be directly compared with the results set forth in the body of the report.

^bBetween River Miles 1.62 and 2.21, some flow leaves the main stem of Underwood Creek and enters the old stream channel. The flows at those river mile locations reflect that diversion.

UNDERWOOD CREEK FLOOD STAGES: EXISTING CHANNEL WITH EXISTING 1995 LAND USE CONDITIONS (FOR COMPARISON WITH APPENDIX B TABLES ONLY)

Location		Flood Stage Elevation (feet above NGVD 1929)							
(River Mile)	Description	Two-Year	10-Year	50-Year	100-Year				
0.06		672.38	675.12	676.66	677.22				
0.11	· · · · · · · · · · · · · · · · · · ·	672.67	675.39	676.91	677.44				
0.22	·····	673.36	676.13	677.72	678.26				
0.225		675.17	677.26	678.63	679.18				
0.23		675.54	677.92	679.50	680.12				
0.33		677.50	680.12	682.29	680.71				
0.42		678.09	680.73	682.84	682.79				
0.46		678.33	680.98	683.04	683.09				
0.468		678.93	681.86	684.01	684.40				
0.475		679.20	682.25	684.44	684.91				
0.49		679.44	682.57	684.77	685.27				
0.491		679.34	682.49	684.70	685.20				
0.495		679.31	682.48	684.71	685.21				
0.52		679.45	682.58	684.79	685.30				
0.63		679.84	682.76	684.87	685.37				
0.635		679.84	681.66	683.91	684.29				
0.67		680.70	683.03	684.83	685.42				
0.675		684.04	685.84	687.18	687.72				
0.72		685.39	687.66	689.25	689.78				
0.725		685.40	687.66	689.25	689.77				
0.73		684.83	687.10	688.68	689.23				
0.74	Downstream USH 45	685.72	688.42	690.19	690.82				
0.76	Upstream USH 45	685.87	688.54	690.29	690.91				
0.8		686.68	689.63	691.55	692.24				
0.805		689.18	691.17	692.69	693.22				
0.81		690.37	692.67	694.41	694.72				
0.8125	Canadian Pacific Railway (bridge)			· · · ·					
0.815		691.33	694.66	698.12	701.49				
0.82		692.29	695.59	698.82	701.64				
0.83		692.35	695.66	698.91	701.69				
0.94		692.33	695.54	698.85	701.66				
1.04		692.67	695.50	698.71	701.55				
1.14		693.47	695.97	698.98	701.71				
1.26		694.51	696.39	698.78	701.47				
1.27	Downstream Mayfair Road	695.66	698.18	700.21	702.28				
1.275	Upstream Mayfair Road	695.67	698.19	700.22	702.28				
1.28		695.08	697.52	699.66	701.95				
1.37		696.44	698.76	700.51	702.27				
1.45		696.78	699.13	700.84	702.43				
1.46		698.18	700.24	701.59	702.11				
1.461	Union Pacific Railroad	699.18	701.58	703.31	703.98				
1.462		699.46	701.88	703.61	704.29				
1.47		701.02	704.70	707.37	708.38				

Location		Flood Stage Elevation (feet above NGVD 1929)					
(River Mile)	Description	Two-Year	10-Year	50-Year	100-Year		
1.49	W. Watertown Plank Road	701.18	704.34	707.18	708.22		
1.53		702.74	705.25	707.60	708.54		
1.535		702.95	704.73	706.82	707.93		
1.59		704.24	706.11	707.27	708.20		
1.595		704.26	706.33	707.68	708.55		
1.62		704.63	706.87	708.29	709.08		
1.63		704.60	706.77	708.14	708.92		
1.635		705.65	707.31	708.55	708.98		
1.69		706.95	708.74	710.05	710.54		
1.695		707.05	708.71	709.95	710.39		
1.79		708.74	710.58	711.88	712.36		
1.86		709.08	710.92	712.23	712.71		
1.87		709.01	710.48	711.26	711.60		
1.8725	N. 115th Street (bridge)						
1.875		709.29	715.83	716.98	719.05		
1.88		709.26	716.20	717.67	719.75		
1.97		711.05	716.39	717.90	719.87		
2.06		711.60	716.47	717.97	719.88		
2.15		712.07	716.58	718.09	719.95		
2.19		712.34	716.64	718.15	719.98		
2.21		712.45	716.79	718.42	720.23		
2.24		712.60	716.74	718.33	720.14		
2.34		713.50	717.37	719.16	720.83		
2.42		713.73	717.57	719.34	720.93		
2.5		714.03	717.58	719.25	720.83		

Location		Flood Stage Elevation (feet above NGVD 1929)						
(River Mile)	Description	Two-Year	10-Year	50-Year	100-Year			
0.06	and the second se	672.43	675.18	676.73	677.28			
0.11		672.71	675.46	676.98	677.50			
0.22		673.41	676.21	677.79	678.33			
0.225		675.20	677.30	678.69	679.21			
0.23		675.56	677.97	679.56	680.22			
0.33		677.53	680.18	682.36	682.94			
0.42		678.12	680.79	682.90	683.44			
0.46		678.36	681.04	683.10	683.68			
0.468		678.96	681.93	684.08	684.75			
0.475		679.23	682.32	684.52	685.22			
0.49		679.48	682.64	684.85	685.56			
0.491		679.37	682.56	684.78	685.49			
0.495		679.34	682.55	684.79	685.51			
0.52		679.48	682.66	684.87	685.59			
0.63		679.87	682.83	684.95	685.64			
0.635		679.86	681.70	683.99	684.69			
0.67		680.72	683.09	684.91	685.63			
0.675		684.06	685.87	687.26	687.77			
0.72		685.42	687.72	689.30	689.83			
0.725		685.42	687.72	689.30	689.83			
0.73		684.84	687.15	688.75	689.29			
0.74	Downstream USH 45	685.74	688.49	690.26	690.89			
0.76	Upstream USH 45	685.90	688.61	690.36	690.97			
0.8		686.72	689.70	691.62	692. <u>3</u> 1			
0.805		689.19	691.21	692.74	693.29			
0.81		690.40	692.72	694.41	694.78			
0.8125	Canadian Pacific Railway (bridge)							
0.815		691.36	694.72	698.16	701.53			
0.82		692.32	695.65	698.87	701.68			
0.83		692.38	695.73	698.96	701.74			
0.94		692.34	695.61	698.90	701.70			
1.04		692.69	695.56	698.76	701.60			
1.14	• •	693.48	696.03	699.03	701.76			
1.26		694.52	696.43	698.82	701.51			
1.27	Downstream Mayfair Road	695.66	698.23	700.26	702.32			
1.275	Upstream Mayfair Road	695.68	698.24	700.27	702.33			
1.28		695.07	697.56	699.69	701.99			
1.37		696.47	698.83	700.57	702.32			
1.45		696.82	699.20	700.90	702.48			
1.46		698.21	700.31	701.69	702.18			
1.461	Union Pacific Railroad	699.21	701.66	703.42	704.10			
1.462		699.50	701.96	703.72	704.40			
1.47		701.07	704.83	707.54	708.54			

UNDERWOOD CREEK FLOOD STAGES: EXISTING CHANNEL WITH PLANNED YEAR 2020 LAND USE CONDITIONS (FOR COMPARISON WITH APPENDIX B TABLES ONLY)

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Location		Flood Stage Elevation (feet above NGVD 1929)					
(River Mile)	Description	Two-Year	10-Year	50-Year	100-Year		
1.49	W. Watertown Plank Road	701.21	704.48	707.36	708.38		
1.53		702.78	705.35	707.76	708.70		
1.535		702.97	704.79	707.01	708.11		
1.59		704.27	706.17	707.42	708.35		
1.595		704.29	706.40	707.82	708.70		
1.62		704.66	706.95	708.42	709.22		
1.63		704.63	706.84	708.26	709.07		
1.635		705.67	707.36	708.62	709.05		
1.69		706.97	708.80	710.14	710.62		
1.695		707.07	708.76	710.02	710.46		
1.79		708.77	710.63	711.96	712.43		
1.86		709.11	710.98	712.31	712.78		
1.87		709.03	710.52	711.27	711.69		
1.8725	N. 115th Street (bridge)		- -				
1.875		709.32	716.16	717.26	719.44		
1.88		709.29	716.53	717.95	720.14		
1.97		711.09	716.70	718.17	720.25		
2.06		711.63	716.78	718.22	720.24		
2.15		712.11	716.88	718.34	720.31		
2.19		712.37	716.93	718.40	720.33		
2.21		712.48	717.08	718.67	720.58		
2.24		712.64	717.03	718.58	720.49		
2.34		713.53	717.63	719.39	721.15		
2.42		713.77	717.81	719.55	721.25		
2.5		714.07	717.81	719.46	721.14		

				R	ecurrence Ir	nterval (years	s)	· · ·	
		Τν	Two 10		50		10	00	
Location (River Mile)	Description	1995 Land Use (cfs)	2020 Land Use (cfs)						
0.00	Confluence with Menomonee River	2,040	2,070	3,880	3,930	5,430	5,490	6,060	6,120
0.76	Upstream side of USH 45	2,030	2,050	3,940	4,000	5,610	5,680	6,300	6,370
1.26	About 590 feet down- stream of Mayfair Road	1,760	1,770	3,390	3,430	4,790	4,840	5,360	5,410
1.53	Upstream side of W. Watertown Plank Road	1,550	1,560	2,990	3,040	4,210	4,280	4,710	4,790
1.62 ^a	Just upstream of location where flow from old channel returns to Underwood Creek	b	1,540	b	2,920	b	4,100	b	4,590
2.21 ^a	Just upstream of location where some flow in Underwood Creek is diverted to old channel	1,550	1,560	2,990	3,040	4,210	4,280	4,710	4,790
2.5	Just downstream from confluence with the South Branch of Underwood Creek	1,250	1,270	2,400	2,460	3,380	3,460	3,780	3,870

UNDERWOOD CREEK FLOOD FLOWS – EXISTING (1995) AND PLANNED (2020) LAND USE CONDITIONS WITH CONCRETE LINING REMOVED AND EXISTING CHANNEL SHAPE AND SIZE (ALTERNATIVE A) (FOR COMPARISON WITH APPENDIX B TABLES ONLY)

^aBetween River Miles 1.62 and 2.21, some flow leaves the main stem of Underwood Creek and enters the old stream channel. The flows at those river mile locations reflect that diversion.

^bNot specifically determined. Requires computation of flood profiles. These flows would be similar to those for 2020 land use conditions.

UNDERWOOD CREEK FLOOD STAGES: PROPOSED ALTERNATIVE A CHANNEL WITH PLANNED YEAR 2020 LAND USE CONDITIONS^a (FOR COMPARISON WITH TABLES B-2 AND B-3 ONLY)

Location		Flood Stage Elevation (feet above NGVD 1929)					
(River Mile)	Description	Two-Year	10-Year	50-Year	100-Year		
0.06		675.36	678.25	679.96	680.60		
0.11		675.66	678.53	680.22	680.86		
0.22		676.36	679.27	680.96	681.60		
0.225		675.92	678.87	680.56	681.21		
0.23		676.13	678.78	680.28	680.90		
0.33		679.00	682.04	683.80	684.34		
0.42		680.10	683.23	684.99	685.57		
0.46		680.51	683.67	685.58	686.22		
0.468		680.71	683.96	685.86	686.51		
0.475		680.84	684.14	686.08	686.75		
0.49		680.97	684.30	686.23	686.89		
0.491		680.94	684.27	686.20	686.86		
0.495		680.94	684.27	686.21	686.87		
0.52		681.05	684.35	686.29	686.95		
0.63		681.42	684.61	686.52	687.18		
0.635		681.30	684.51	686.42	687.09		
0.67		681.93	684.82	686.67	687.31		
0.675		683.72	685.33	686.38	686.91		
0.72		686.19	688.08	689.33	689.72		
0.725		686.19	688.08	689.33	689.73		
0.73		686.28	687.86	688.66	688.79		
0.74	Downstream USH 45	686.69	688.79	690.30	690.94		
0.76	Upstream USH 45	687.12	689.45	691.01	691.62		
0.8		687.73	690.37	692.10	692.77		
0.805		688.88	690.76	692.48	693.00		
0.81		690.06	692.11	693.57	694.41		
0.8125	Canadian Pacific Railway (bridge)						
0.815		691.63	694.74	698.32	699.84		
0.82		692.23	695.27	698.68	699.99		
0.83		692.39	695.39	698.77	700.07		
0.94		693.01	695.78	698.99	700.24		
1.04		694.19	696.60	699.31	700.49		
1.14		695.38	697.96	700.18	701.19		
1.26		696.54	698.89	700.77	701.64		
1.27	Downstream Mayfair Road	696.85	699.32	701.22	702.10		
1.275	Upstream Mayfair Road	696.90	699.39	701.29	702.15		
1.28	 A state of the sta	696.90	699.36	701.22	702.06		
1.37		698.18	700.88	702.65	703.41		
1.45		698.76	701.55	703.27	703.97		
1.46		698.33	701.17	702.85	703.52		
1.461	Union Pacific Railroad	698.85	701.14	702.80	703.43		
1.462		700.36	703.09	705.02	705.76		

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		Flood S	Stage Elevation (1	eet above NGVE) 1929)
(River Mile)	Description	Two-Year	10-Year	50-Year	100-Year
1.47		701.23	704.69	707.20	708.16
1.49	W. Watertown Plank Road	701.57	704.92	707.35	708.27
1.53		703.27	706.10	708.25	709.10
1.535		702.70	705.58	707.90	708.79
1.59		705.40	707.42	709.07	709.78
1.595		705.43	707.48	709.12	709.82
1.62		705.82	708.01	709.67	710.35
1.63		705.89	708.08	709.74	710.42
1.635		705.35	707.04	708.89	709.64
1.69		708.01	710.08	711.34	711.84
1.695		707.74	709.74	710.92	711.42
1.79		709.92	712.08	713.51	714.03
1.86		710.56	712.82	714.30	714.85
1.87		710.56	712.66	713.95	714.40
1.8725	N. 115th Street (bridge)				
1.875		711.43	714.80	718.78	720.61
1.88		711.56	715.18	719.28	721.16
1.97		712.59	715.82	719.52	721.30
2.06		713.35	716.41	719.82	721.51
2.15		713.98	716.96	720.13	721.73
2.19		714.28	717.21	720.26	721.82
2.21		714.38	717.39	720.44	721.98
2.24		714.56	717.49	720.48	722.00
2.34		715.20	718.08	720.90	722.35
2.42		715.55	718.32	721.00	722.42
2.5		715.89	718.47	721.00	722.39

^aConcrete lining removed in Wauwatosa, existing channel cross-section in Wauwatosa, and existing channel upstream of Wauwatosa.

COMPARISON OF FLOOD STAGES ALONG UNDERWOOD CREEK (FOR COMPARISON WITH APPENDIX B TABLES ONLY)

TWO-YEAR RECURRENCE INTERVAL

		Flood Stage Elevation (feet above NGVD 1929)						
Location		Two-Year	Two-Year	Change in	Two-Year	Change in	Two-Year	Change in
(River Mile)	Description	Existing ^a	Alternative A	Stage (feet)	Alternative B	Stage (feet)	Alternative C	Stage (feet)
0.06		672.43	675.36	2.93	675.12	2.69	675.07	2.64
0.11		672.71	675.66	2.95	675.42	2.71	675.37	2.66
0.22		673.41	676.36	2.95	676.11	2.70	676.07	2.66
0.225		675.20	675.92	0.72	675.64	0.44	675.59	0.39
0.23		675.56	676.13	0.57	675.90	0.34	675.86	0.30
0.33		677.53	679.00	1.47	678.80	1.27	678.76	1.23
0.42		678.12	680.10	1.98	679.88	1.76	679.84	1.72
0.46		678.36	680.51	2.15	680.28	1.92	680.24	1.88
0.468		678.96	680.71	1.75	680.48	1.52	680.43	1.47
0.475		679.23	680.84	1.61	680.60	1.37	680.53	1.30
0.49		679.48	680.97	1.49	680.73	1.25	680.69	1.21
0.491		679.37	680.94	1.57	680.70	1.33	680.66	1.29
0.495		679.34	680.94	1.60	680.70	1.36	680.66	1.32
0.52		679.48	681.05	1.57	680.81	1.33	680.76	1.28
0.63		679.87	681.42	1.55	681.20	1.33	681.16	1.29
0.635		679.86	681.30	1.44	681.07	1.21	681.03	1.17
0.67		680.72	681.93	1.21	681.75	1.03	681.72	1.00
0.675		684.06	683.72	-0.34	683.61	-0.45	683.59	-0.47
0.72		685.42	686.19	0.77	686.05	0.63	686.03	0.61
0.725		685.42	686.19	0.77	686.06	0.64	686.03	0.61
0.73		684.84	686.28	1.44	686.16	1.32	686.14	1.30
0.74	Downstream USH 45	685.74	686.69	0.95	686.54	0.80	686.51	0.77
0.76	Upstream USH 45	685.90	687.12	1.22	686.96	1.06	686.93	1.03
0.8		686.72	687.73	1.01	687.55	0.83	687.52	0.80
0.805		689.19	688.88	-0.31	688.72	-0.47	688.68	-0.51
0.81		690.40	690.06	-0.34	689.90	-0.50	689.86	-0.54
0.8125	Canadian Pacific Railway (bridge)				'	·	·	
0.815		691.36	691.63	0.27	691.38	0.02	691.31	-0.05
0.82		692.32	692.23	-0.09	691.98	-0.34	691.92	-0.40
0.83		692.38	692.39	0.01	692.15	-0.23	692.08	-0.30
0.94		692.34	693.01	0.67	692.81	0.47	692.75	0.41
1.04		692.69	694.19	1.50	693.64	0.95	693.60	0.91
1.14		693.48	695.38	1.90	694.81	1.33	694.77	1.29
1.26		694.52	696.54	2.02	695.74	1.22	695.71	1.19
1.27	Downstream Mayfair Road	695.66	696.85	1.19	696.15	0.49	696.11	0.45
1.275	Upstream Mayfair Road	695.68	696.90	1.22	696.21	0.53	696.17	0.49
1.28		695.07	696.90	1.83	696.23	1.16	696.19	1.12
1.37		696.47	698.18	1.71	697.77	1.30	697.72	1.25
1.45		696.82	698.76	1.94	698.40	1.58	698.35	1.53
1.46		698.21	698.33	0.12	697.86	-0.35	697.80	-0.41
1.461	Union Pacific Railroad	699.21	698.85	-0.36	698.67	-0.54	698.64	-0.57
1.462		699.50	700.36	0.86	700.15	0.65	700.11	0.61
1.47		701.07	701.23	0.16	700.97	-0.10	700.92	-0.15
1.49	W. Watertown Plank Road	701.21	701.57	0.36	701.32	0.11	701.27	0.06
1.53		702.78	703.27	0.49	703.06	0.28	703.02	0.24
1.535		702.97	702.70	-0.27	702.55	-0.42	702.53	-0.44
1.59		704.27	705.40	1.13	705.20	0.93	705.17	0.90
1.595		704.29	705.43	1.14	705.20	0.91	705.17	0.88
1.62		704.66	705.82	1.16	705.59	0.93	705.55	0.89
1.63		704.63	705.89	1.26	705.72	1.09	705.68	1.05
1.635		705.67	705.35	-0.32	705.23	-0.44	705.22	-0.45

			- <u></u>	lood Stage Elev	ation (feet abov	e NGVD 1929)		
Location (River Mile)	Description	Two-Year Existing ^a	Two-Year Alternative A	Change in Stage (feet)	Two-Year Alternative B	Change in Stage (feet)	Two-Year Alternative C	Change in Stage (feet)
1.69		706.97	708.01	1.04	707.84	0.87	707.80	0.83
1.695		707.07	707.74	0.67	707.54	0.47	707.51	0.44
1.79		708.77	709.92	1.15	709.59	0.82	709.56	0.79
1.86		709.11	710.56	1.45	710.04	0.93	710.01	0.90
1.87	-	709.03	710.56	1.53	710.06	1.03	710.03	1.00
1.8725	N. 115th Street (bridge)					·		
1.875		709.32	711.43	2.11	710.13	_0.81	710.10	0.78
1.88		709.29	711.56	2.27	710.27	0.98	710.24	0.95
1.97		711.09	712.59	1.50	712.00	0.91	711.96	0.87
2.06		711.63	713.35	1.72	712.78	1.15	712.74	1.11
2.15		712.11	713.98	1.87	713.43	1.32	713.39	1.28
2.19		712.37	714.28	1.91	713.71	1.34	713.67	1.30
2.21		712.48	714.38	1.90	713.80	1.32	713.76	1.28
2.24		712.64	714.56	1.92	713.97	1.33	713.93	1.29
2.34		713.53	715.20	1.67	714.35	0.82	714.31	0.78
2.42		713.77	715.55	1.78	714.50	0.73	714.46	0.69
2.5		714.07	715.89	1.82	715.12	1.05	715.07	1.00

10-YEAR RECURRENCE INTERVAL

				Flood Stage Elev	vation (Feet abov	ve NGVD 1929)		
Location (River Mile)	Description	10-Year Existing ^a	10-Year Alternative A	Change in Stage (feet)	10-Year Alternative B	Change in Stage (feet)	10-Year Alternative C	Change in Stage (feet)
0.06		675.18	678.25	3.07	677.90	2.72	677.88	2.70
0,11		675.46	678.53	3.07	678.18	2.72	678.17	2.71
0.22		676.21	679.27	3.06	678.91	2.70	678.90	2.69
0.225		677.30	678.87	1.57	678.53	1.23	678.52	1.22
0.23		677.97	678.78	0.81	678.46	0.49	678.45	0.48
0.33		680.18	682.04	1.86	681.60	1.42	681.59	1.41
0.42		680.79	683.23	2.44	682.79	2.00	682.78	1.99
0.46		681.04	683.67	2.63	683.22	2.18	683.20	2.16
0.468		681.93	683.96	2.03	683.50	1.57	683.48	1.55
0.475		682.32	684.14	1.82	683.67	1.35	683.65	1.33
0.49		682.64	684.30	1.66	683.83	1.19	683.81	1.17
0.491		682.56	684.27	1.71	683.80	1.24	683.78	1.22
0.495		682.55	684.27	1.72	683.80	1.25	683.79	1.24
0.52		682.66	684.35	1.69	683.88	1.22	683.86	1.20
0.63		682.83	684.61	1.78	684.16	1.33	684.14	1.31
0.635		681.70	684.51	2.81	684.05	2.35	684.03	2.33
0.67		683.09	684.82	1.73	684.38	1.29	684.37	1.28
0.675		685.87	685.33	-0.54	685.07	-0.80	685.07	-0.80
0.72		687.72	688.08	0.36	687.82	0.10	687.81	0.09
0.725		687.72	688.08	0.36	687.82	0.10	687.81	0.09
0.73		687.15	687.86	0.71	687.66	0.51	687.66	0.51
0.74	Downstream USH 45	688.49	688.79	0.30	688.48	-0.01	688.47	-0.02
0.76	Upstream USH 45	688.61	689.45	0.84	689.11	0.50	689.10	0.49
0.8		689.70	690.37	0.67	689.99	0.29	689.98	0.28
0.805		691.21	690.76	-0.45	690.48	-0.73	690.47	-0.74
0.81		692.72	692.11	-0.61	691.79	-0.93	691.76	-0.96
0.8125	Canadian Pacific Railway (bridge)						1 - 1 - <u>-</u>	
0.815		694.72	694.74	0.02	694.39	-0.33	694.38	-0.34
0.82		695.65	695.27	-0.38	694.90	-0.75	694.89	-0.76
0.83		695.73	695.39	-0.34	695.02	-0.71	695.00	-0.73
0.94		695.61	695.78	0.17	695.45	-0.16	695.44	-0.17
1.04		695.56	696.60	1.04	695.71	0.15	695.70	0.14

				Flood Stage Ele	vation (Feet abo	ve NGVD 1929)		
Location (River Mile)	Description	10-Year Existing ^a	10-Year Alternative A	Change in Stage (feet)	10-Year Alternative B	· Change in Stage (feet)	10-Year Alternative C	Change in Stage (feet)
1.14		696.03	697.96	1.93	696.66	0.63	696.64	0.61
1.26		696.43	698.89	2.46	696.92	0.49	696.91	0.48
1.27	Downstream Mayfair Road	698.23	699.32	1.09	697.81	-0.42	697.80	-0.43
1.275	Upstream Mayfair Road	698.24	699.39	1.15	697.92	-0.32	697.91	-0.33
1.28		697.56	699.36	1.80	697.90	0.34	697.89	0.33
1.37		698.83	700.88	2.05	700.15	1.32	700.12	1.29
1.45		699.20	701.55	2.35	700.93	1.73	700.90	1.70
1.46		700.31	701.17	0.86	700.50	0.19	700.47	0.16
1.461	Union Pacific Railroad	701.66	701.14	-0.52	700.78	-0.88	700.75	-0.91
1.462		701.96	703.09	1.13	702.67	0.71	702.64	0.68
1.47		704.83	704.69	-0.14	704.14	-0.69	704.10	-0.73
1.49	W. Watertown Plank Road	704.48	704.92	0.44	704.39	-0.09	704.34	-0.14
1.53		705.35	706.10	0.75	705.64	0.29	705.60	0.25
1.535		704.79	705.58	0.79	705.07	0.28	705.03	0.24
1.59		706.17	707.42	1.25	707.15	0.98	707.12	0.95
1.595		706.40	707.48	1.08	707.07	0.67	707.04	0.64
1.62		706.95	708.01	1.06	707.55	0.60	707.53	0.58
1.63		706.84	708.08	1.24	707.75	0.91	707.73	0.89
1.635		707.36	707.04	-0.32	707.47	0.11	707.46	0.10
1.69		708.80	710.08	1.28	709.16	0.36	709.15	0.35
1.695		708.76	709.74	0.98	708.77	0.01	708.73	-0.03
1.79		710.63	712.08	1.45	711.01	0.38	711.01	0.38
1.86		710.98	712.82	1.84	711.19	0.21	711.18	0.20
1.87		710.52	712.66	2.14	711.11	0.59	711.10	0.58
1.8725	N. 115th Street (bridge)						·	
1.875		716.16	714.80	-1.36	712.63	-3.53	712.59	-3.57
1.88		716.53	715.18	-1.35	713.08	-3.45	713.04	-3.49
1.97		716.70	715.82	-0.88	714.36	-2.34	714.32	-2.38
2.06		716.78	716.41	-0.37	714.95	-1.83	714.92	-1.86
2.15		716.88	716.96	0.08	715.57	-1.31	715.54	-1.34
2.19		716.93	717.21	0.28	715.82	-1.11	715.79	-1.14
2.21		717.08	717.39	0.31	715.94	-1.14	715.91	-1.17
2.24		717.03	717.49	0.46	716.06	-0.97	716.03	-1.00
2.34		717.63	718.08	0.45	716.35	-1.28	716.32	-1.31
2.42		717.81	718.32	0.51	716.38	-1.43	716.36	-1.45
2.5		717.81	718.47	0.66	716.95	-0.86	716.92	-0.89

50-YEAR RECURRENCE INTERVAL

				Flood Stage Ele	vation (Feet abo	ve NGVD 1929)	
Location (River Mile)	Description	50-Year Existing ^a	50-Year Alternative A	Change in Stage (feet)	50-Year Alternative B	Change in Stage (feet)	50-Year Alternative C	Change in Stage (feet)
0.06		676.73	679.96	3.23	679.52	2.79	679.53	2.80
0.11		676.98	680.22	3.24	679.79	2.81	679.80	2.82
0.22		677.79	680.96	3.17	680.53	2.74	680.54	2.75
0.225		678.69	680.56	1.87	680.15	1.46	680.16	1.47
0.23		679.56	680.28	0.72	679.93	0.37	679.94	0.38
0.33		682.36	683.80	1.44	683.29	0.93	683.30	0.94
0.42		682.90	684.99	2.09	684.48	1.58	684.49	1.59
0.46		683.10	685.58	2.48	685.02	1.92	685.03	1.93
0.468		684.08	685.86	1.78	685.30	1.22	685.32	1.24
0.475	· · · · · · · · · · · · · · · · · · ·	684.52	686.08	1.56	685.51	0.99	685.52	1.00
0.49		684.85	686.23	1.38	685.66	0.81	685.68	0.83
0.491		684.78	686.20	1.42	685.64	0.86	685.65	0.87
0.495		684.79	686.21	1.42	685.64	0.85	685.65	0.86

		Flood Stage Elevation (Feet above NGVD 1929)								
Location		50-Vear	50-Year	Change in	50-Vear	Change in	50-Vear	Change in		
(River Mile)	Description	Existing ^a	Alternative A	Stage (feet)	Alternative B	Stage (feet)	Alternative C	Stage (feet)		
0.52		684.87	686.29	1.42	685.72	0.85	685.73	0.86		
0.63		684.95	686.52	1.57	685.96	1.01	685.97	1.02		
0.635		683.99	686.42	2.43	685.86	1.87	685.87	1.88		
0.67		684.91	686.67	1.76	686,12	1.21	686.13	1.22		
0.675		687.26	686.38	-0.88	685.98	-1.28	685.99	-1.27		
0.72		689.30	689.33	0.03	688.97	-0.33	688.97	-0.33		
0.725	· · · · · · · · · · · · · · · · · · ·	689.30	689.33	0.03	688.97	-0.33	688.98	-0.32		
0.73		688.75	688.66	-0.09	688.46	-0.29	688.47	-0.28		
0.74	Downstream USH 45	690.26	690.30	0.04	689.84	-0.42	689,85	-0.41		
0.76	Upstream USH 45	690.36	691.01	0.65	690.54	0.18	690.55	0.19		
0.8		691.62	692.10	0.48	691.58	-0.04	691.59	-0.03		
0.805		692.74	692.48	-0.26	691.97	-0.77	691.97	-0.77		
0.81		694.41	693.57	-0.84	693.15	-1.26	693.15	-1.26		
0.8125	Canadian Pacific Railway (bridge)	· · · ·						·		
0.815		698.16	698.32	0.16	697.52	-0.64	697.52	-0.64		
0,82		698.87	698.68	-0.19	697.83	-1.04	697.83	-1.04		
0.83		698.96	698.77	-0.19	697.92	-1.04	697.92	-1.04		
0.94		698.90	698.99	0.09	698.20	-0.70	698.20	-0.70		
1.04		698.76	699.31	0.55	698.27	-0.49	698.27	-0.49		
1.14		699.03	700.18	1.15	698.80	-0.23	698.80	-0.23		
1.26		698.82	700.77	1.95	698.45	-0.37	698.45	-0.37		
1.27	Downstream Mayfair Road	700.26	701.22	0.96	699.39	-0.87	699.39	-0.87		
1.275	Upstream Mayfair Road	700.27	701.29	1.02	699.50	-0.77	699.50	-0.77		
1.28		699.69	701.22	1.53	699.45	-0.24	699.45	-0.24		
1.37		700.57	702.65	2.08	701.73	1.16	701.73	1,16		
1.45		700.90	703.27	2.37	702.51	1.61	702.51	1.61		
1.46		701.69	702.85	1.16	702.03	0.34	702.03	0.34		
1.461	Union Pacific Railroad	703.42	702.80	-0.62	702.34	-1.08	702.34	-1.08		
1.462	· · · · · · · · · · · · · · · · · · ·	703.72	705.02	1.30	704.50	0.78	704.50	0.78		
1.47		707.54	707.20	-0.34	706.52	-1.02	706.52	1.02		
1.49	W. Watertown Plank Road	707.36	707.35	-0.01	706.69	-0.67	706.69	-0.67		
1.53		707.76	708.25	0.49	707.66	-0.10	707.66	-0.10		
1.535		707.01	707.90	0.89	707.28	0.27	707.28	0.27		
1.59		707.42	709.07	1.65	708.87	1.45	708.87	1.45		
1.595		707.82	709.12	1.30	708.83	1.01	708.83	1.01		
1.62		708.42	709.67	1.25	709.04	0.62	709.04	0.62		
1.63		708.26	709.74	1.48	709.19	0.93	709.19	0.93		
1.635		708.62	708.89	0.27	708.97	0.35	708.97	0.35		
1.69		710.14	711.34	1.20	709.79	-0.35	709.79	-0.35		
1.695		710.02	710.92	0.90	709.34	-0.68	709.34	-0.68		
1.79		711.96	713.51	1.55	711.81	-0.15	711.81	-0.15		
1.86		712.31	714.30	1.99	711.74	-0.57	711.74	-0.57		
1.87		711.27	713.95	2.68	711.47	0.20	711.47	0.20		
1.8725	N. 115th Street (bridge)							x		
1.875		717.26	718.78	1.52	715.18	-2.08	715.18	-2.08		
1.88		717.95	719.28	1.33	715.84	-2.11	715.84	-2.11		
1.97		718.17	719.52	1.35	716.67	-1.50	716.67	-1.50		
2.06		718.22	719.82	1.60	717.06	-1.16	717.06	-1.16		
2.15		718.34	720.13	1.79	717.54	-0.80	717.54	-0.80		
2.19		718.40	720.26	1.86	717.72	-0.68	717 72	-0.68		
2.21	· · · · · · · · · · · · · · · · · · ·	718.67	720.44	1.77	717.84	-0.83	717.84	-0.83		
2.24		718.58	720.48	1.90	717.92	-0.66	717.92	-0.66		
2.34		719.39	720.90	1.51	718.15	-1.24	718.15	-1.24		
2.42		719.55	721.00	1.45	718.17	-1.38	718.17	-1.38		
2.5		719.46	721.00	1.54	718.41	-1.05	718.41	-1.05		

100-YEAR RECURRENCE INTERVAL

				Flood Stage Fle	vation (Feet abo	ve NGVD 1929		
		100 1	100 1	Channel in	100 Var-	Change in	100 Voor	Change in
Location (River Mile)	Description	Existing ^a	Alternative A	Stage (feet)	Alternative B	Stage (feet)	Alternative C	Stage (feet)
0.06		677.28	680.60	3.32	680.10	2.82	680.12	2.84
0.11		677.50	680.86	3.36	680.36	2.86	680.38	2.88
0.22		678.33	681.60	3.27	681.11	2.78	681.13	2.80
0.225		679.21	681.21	2.00	680.72	1.51	680.74	1.53
0.23		680.22	680.90	0.68	680.45	0.23	680.47	0.25
0.33		682.94	684.34	1.40	683.86	0.92	683.88	0.94
0.42		683.44	685.57	2.13	685.06	1.62	685.07	1.63
0.46		683.68	686.22	2.54	685.65	1.97	685.67	1.99
0.468		684.75	686.51	1.76	685.94	1.19	685.96	1.21
0.475		685.22	686.75	1.53	686.16	0.94	686.18	0.96
0.49		685.56	686.89	1.33	686.31	0.75	686.33	0.77
0.491		685.49	686.86	1.37	686.28	079	686.30	0.81
0.495	· ·	685.51	686.87	1.36	686.29	0.78	686.31	0.80
0.52		685.59	686.95	1.36	686.37	0.78	686.62	0.80
0.63	· · · · · · · · · · · · · · · · · · ·	684.60	687.18	1.54	696 50	0.90	686.52	1.83
0.635		695.62	697.09	1.69	686.75	1.01	686 77	1 14
0.07	1	687 77	686.01	-0.86	686.45	-1 32	686.46	1 31
0.075		689.83	680.77	-0.11	689.37	-0.46	689.39	-0.44
0.72		689.83	689.72	-0.10	689.38	-0.45	689.39	-0.44
0.723		689.29	688.79	-0.50	688 68	-0.61	688.69	-0.60
0.73	Dowostream USH 45	690.89	690.94	0.05	690.37	-0.52	690.39	-0.50
0.74	Linstream USH 45	690.97	691.62	0.65	691.08	0.11	691.09	0.12
0.90		692.31	692.77	0.46	692.17	-0.14	692.19	-0.12
0.805		693.29	693.00	-0.29	692.59	-0.70	692.61	-0.68
0.81		694.78	694.41	-0.37	693.67	-1.11	693.69	-1.09
0.8125	Canadian Pacific Railway (bridge)							
0.815		701.53	699.84	-1.69	698,49	-3.04	698.52	-3.01
0.82		701.68	699.99	-1.69	698.82	-2.86	698.84	-2.84
0.83		701.74	700.07	-1.67	698.91	-2.83	698.93	-2.81
0.94		701.70	700.24	-1.46	699.18	-2.52	699.20	-2.50
1.04		701.60	700.49	-1.11	699.23	-2.37	699.25	-2.35
1.14		701.76	701.19	-0.57	699.68	-2.08	699.69	-2.07
1.26		701.51	701.64	0.13	699.23	-2.28	699.24	-2.27
1.27	Downstream Mayfair Road	702.32	702.10	-0.22	700.09	-2.23	700.10	-2.22
1.275	Upstream Mayfair Road	702.33	702.15	-0.18	700.20	-2.13	700.21	-2.12
1.28		701.99	702.06	0.07	700.14	-1.85	700.15	-1.84
1.37		702.32	703.41	1.09	702.32	0.00	702.34	0.02
1.45		702.48	703.97	1.49	703.09	0.61	703.11	0.63
1.46		702.18	703.52	1.34	702.60	0.42	702.62	0.44
1.461	Union Pacific Railroad	704.10	703.43	-0.67	702.94	-1.16	702.97	-1.13
1.462		704.40	705.76	1.36	705.17	0.77	705.19	0.79
1.47		708.54	708.16	-0.38	707.41	-1.13	/07.44	-1.10
1.49	W. Watertown Plank Road	708.38	708.27	-0.11	707.55	-0.83	707.58	-0.80
1.53		/08.70	709.10	0.40	708.43	-0.27	708.46	-0.24
1.535		708.11	/08.79	0.68	708.10	-0.01	708.13	1.24
1.59		708.35	709.78	1.43	709.50	1.21	709.59	0.24
1.595		708.70	709.82	1.12	709.54	0.84	709.37	0.67
1.62	· · · · · · · · · · · · · · · · · · ·	709.22	710.35	1.13	709.09	0.47	709.72	0.00
1.03		709.07	710.42	0.50	709.02	0.75	709.05	0.65
1.035		710.62	711 94	1 22	710.26	-0.36	710.28	-0.34
1 695		710.02	711.04	0.006	710.20	-0.42	710.07	-0.39
1 70		712.40	714.02	1.60	711 96	-0.42	711 97	-0.46
1.79		/12.43	/14.03	1.00	/11.90	-0.+/	/11.3/	-0,+0

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				Flood Stage Ele	vation (Feet abo	ve NGVD 1929))		
Location (River Mile)	Description	100-Year Existing ^a	100-Year Alternative A	Change in Stage (feet)	100-Year Alternative B	Change in Stage (feet)	100-Year Alternative C	Change in Stage (feet)	
1.86		712.78	714.85	2.07	711.81	-0.97	711.81	-0.97	
1.87		711.69	714.40	2.71	711.41	-0.28	711.41	-0.28	
1.8725	N. 115th Street (bridge)		'	·	· · · · · · · · ·				
1.875		719.44	720.61	1.17	716.24	-3.20	716.29	-3.15	
1.88		720.14	721.16	1.02	716.96	-3.18	717.01	-3.13	
1.97		720.25	721.30	1.05	717.67	-2.58	717.72	-2.53	
2.06		720.24	.721.51	1.27	717.99	-2.25	718.04	-2.20	
2.15		720.31	721.73	1.42	718.41	-1.90	718.45	-1.86	
2.19		720.33	721.82	1.49	718.57	-1.76	718.61	-1.72	
2.21		720.58	721.98	1.40	718.68	-1.90	718.72	-1.86	
2.24		720.49	722.00	1.51	718.75	-1.74	718.79	-1.70	
2.34		721.15	722.35	1.20	718.95	-2.20	718.99	-2.16	
2.42		721.25	722.42	.1.17	718.98	-2.27	719.01	-2.24	
2.5		721.14	722.39	1.25	719.10	-2.04	719.13	-2.01	

^aPlanned year 2020 land use, existing channel conditions.

					_				
		T\	NO	10		50		10	00
Location (River Miles)	Description	1995 Land Use (cfs)	2020 Land Use (cfs)						
0.00	Confluence with Menomonee River	1,930	1,960	3,600	3,650	5,000	5,060	5,560	5,630
0.76	Upstream side of USH 45	1,910	1,940	3,620	3,670	5,090	5,150	5,700	5,760
1.26	About 590 feet down- stream of Mayfair Road	1,650	1,660	3,100	3,140	4,360	4,420	4,880	4,950
1.53	Upstream side of W. Watertown Plank Road	1,450	1,460	2,740	2,790	3,860	3,930	4,320	4,390
1.62 ^a	Just upstream of location where flow from old channel returns to Underwood Creek	b	1,450	b	2,720	b	3,800	b	4,240
2.21 ^a	Just upstream of location where some flow in Underwood Creek is diverted to old channel	1,450	1,460	2,740	2,790	3,860	3,930	4,320	4,390
2.5	Just downstream from confluence with the South Branch of Underwood Creek	1,190	1,220	2,290	2,350	3,250	3,340	3,650	3,740

UNDERWOOD CREEK FLOOD FLOWS—EXISTING (1995) AND PLANNED (2020) LAND USE CONDITIONS WITH CONCRETE LINING REMOVED AND EXPANDED CHANNEL CROSS-SECTION (ALTERNATIVE B) (FOR COMPARISON WITH APPENDIX B TABLES ONLY)

^aBetween River Miles 1.62 and 2.21, some flow leaves the main stem of Underwood Creek and enters the old stream channel. The flows at those river mile locations reflect that diversion.

^bNot specifically determined. Requires computation of flood profiles. These flows would be similar to those for 2020 land use conditions.

Location		Flood S	Stage Elevation (f	eet above NGVD	1929)
(River Mile)	Description	Two-Year	10-Year	50-Year	100-Year
0.06		675.12	677.90	679.52	680.10
0.11		675.42	678.18	679.79	680.36
0.22		676.11	678.91	680.53	681.11
0.225		675.64	678.53	680.15	680.72
0.23		675.90	678.46	679.93	680.45
0.33		678.80	681.60	683.29	683.86
0.42		679.88	682.79	684.48	685.06
0.46		680.28	683.22	685.02	685.65
0.468		680.48	683.50	685.30	685.94
0.475		680.60	683.67	685.51	686.16
0.49		680.73	683.83	685.66	686.31
0.491		680.70	683.80	685.64	686.28
0.495		680.70	683.80	685.64	686.29
0.52		680.81	683.88	685.72	686.37
0.63		681.20	684.16	685.96	686.60
0.635		681.07	684.05	685.86	686.50
0.67		681.75	684.38	686.12	686.75
0.675		683.61	685.07	685.98	686.45
0.72		686.05	687.82	688.97	689.37
0.725		686.06	687.82	688.97	689.38
0.73		686.16	687.66	688.46	688.68
0.74	Downstream USH 45	686.54	688.48	689.84	690.37
0.76	Upstream USH 45	686.96	689.11	690.54	691.08
0.8		687.55	689.99	691.58	692.17
0.805		688.72	690.48	691.97	692.59
0.81		689.90	691.79	693.15	693.67
0.8125	Canadian Pacific Railway (bridge)				
0.815		691.38	694.39	697.52	698.49
0.82		691.98	694.90	697.83	698.82
0.83		692.15	695.02	697.92	698.91
0.94		692.81	695.45	698.20	699.18
1.04		693.64	695.71	698.27	699.23
1.14		694.81	696.66	698.80	699.68
1.26		695.74	696.92	698.45	699.23
1.27	Downstream Mayfair Road	696.15	697.81	699.39	700.09
1.275	Upstream Mayfair Road	696.21	697.92	699.50	700.20
1.28		696.23	697.90	699.45	700.14
1.37		697.77	700.15	701.73	702.32
1.45		698.40	700.93	702.51	703.09
1.46		697.86	700.50	702.03	702.60
1.461	Union Pacific Railroad	698.67	700.78	702.34	702.94
1.462		700.15	702.67	704.50	705.17

UNDERWOOD CREEK FLOOD STAGES: PROPOSED ALTERNATIVE B CHANNEL WITH PLANNED YEAR 2020 LAND USE CONDITIONS^a (FOR COMPARISON WITH APPENDIX B TABLES ONLY)

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		Flood Stage Elevation (feet above NGVD 1929)					
(River Mile)	Description	Two-Year	10-Year	50-Year	100-Year		
1.47		700.97	704.14	706.52	707.41		
1.49	W. Watertown Plank Road	701.32	704.39	706.69	707.55		
1.53		703.06	705.64	707.66	708.43		
1.535		702.55	705.07	707.28	708.10		
1.59		705.20	707.15	708.87	709.56		
1.595		705.20	707.07	708.83	709.54		
1.62		705.59	707.55	709.04	709.69		
1.63		705.72	707.75	709.19	709.82		
1.635		705.23	707.47	708.97	709.67		
1.69		707.84	709.16	709.79	710.26		
1.695		707.54	708.77	709.34	710.04		
1.79		709.59	711.01	711.81	711.96		
1.86		710.04	711.19	711.74	711.81		
1.87		710.06	711.11	711.47	711.41		
1.8725	N. 115th Street (bridge)						
1.875		710.13	712.63	715.18	716.24		
1.88		710.27	713.08	715.84	716.96		
1.97		712.00	714.36	716.67	717.67		
2.06		712.78	714.95	717.06	717.99		
2.15		713.43	715.57	717.54	718.41		
2.19		713.71	715.82	717.72	718.57		
2.21		713.80	715.94	717.84	718.68		
2.24		713.97	716.06	717.92	718.75		
2.34		714.35	716.35	718.15	718.95		
2.42		714.50	716.38	718.17	718.98		
2.5		715.12	716.95	718.41	719.10		

^aConcrete lining removed in Wauwatosa, expanded channel cross-section in Wauwatosa, and existing channel upstream of Wauwatosa.

		Recurrence Interval (years)								
		T	Two		10		50		00	
Location (River Miles)	Description	1995 Land Use (cfs)	2020 Land Use (cfs)	1995 Land Use (cfs)	2020 Land Use (cfs)	1995 Land Use (cfs)	2020 Land Use (cfs)	1995 Land Use (cfs)	2020 Land Use (cfs)	
0.00	Confluence with Menomon ce River	1,910	1,940	3,590	3,640	5,010	5,070	5,580	5,650	
0.76	Upstream side of USH 45	1,890	1,920	3,610	3,660	5,100	5,160	5,720	5,780	
1.26	About 590 feet down- stream of Mayfair Road	1,630	1,630	3,090	3,130	4,370	4,420	4,900	4,960	
1.53	Upstream side of W. Watertown Plank Road	1,420	1,440	2,720	2,770	3,860	3,930	4,330	4,410	
1.62 ^a	Just upstream of location where flow from old channel returns to Underwood Creek	p	1,430	b	2,700	b	3,800	b	4,260	
2.21 ^a	Just upstream of location where some flow in Underwood Creek is diverted to old channel	1,420	1,440	2,720	2,770	3,860	3,930	4,330	4,410	
2.5	Just downstream from confluence with the South Branch of Underwood Creek	1,170	1,190	2,270	2,330	3,250	3,340	3,660	3,760	

UNDERWOOD CREEK FLOOD FLOWS-EXISTING (1995) AND PLANNED (2020) LAND USE CONDITIONS WITH CONCRETE LINING REMOVED, EXPANDED CHANNEL CROSS-SECTIONS, AND PROPOSED OVERFLOW CHANNEL ALTERNATIVE IN THE VILLAGE OF ELM GROVE (ALTERNATIVE C) (FOR COMPARISON WITH APPENDIX B TABLES ONLY)

^aBetween River Miles 1.62 and 2.21, some flow leaves the main stem of Underwood Creek and enters the old stream channel. The flows at those river mile locations reflect that diversion.

^bNot specifically determined. Requires computation of flood profiles. These flows would be similar to those for 2020 land use conditions.

UNDERWOOD CREEK FLOOD STAGES: PROPOSED
ALTERNATIVE C CHANNEL WITH PLANNED YEAR 2020 LAND USE CONDITIONS ⁸
(FOR COMPARISON WITH APPENDIX B TABLES ONLY)

Location		Flood Stage Elevation (feet above NGVD 1929)					
(River Mile)	Description	Two-Year	10-Year	50-Year	100-Year		
0.06		675.07	677.88	679.53	680.12		
0.11		675.37	678.17	679.80	680.38		
0.22		676.07	678.90	680.54	681.13		
0.225		675.59	678.52	680.16	680.74		
0.23		675.86	678.45	679.94	680.47		
0.33		678.76	681.59	683.30	683.88		
0.42		679.84	682.78	684.49	685.07		
0.46		680.24	683.20	685.03	685.67		
0.468		680.43	683.48	685.32	685.96		
0.475		680.56	683.65	685.52	686.18		
0.49		680.69	683.81	685.68	686.33		
0.491		680.66	683.78	685.65	686.30		
0.495		680.66	683.79	685.65	686.31		
0.52		680.76	683.86	685.73	686.39		
0.63		681.16	684.14	685.97	686.62		
0.635		681.03	684.03	685.87	686.52		
0.67		681.72	684.37	686.13	686.77		
0.675		683.59	685.07	685.99	686.46		
0.72		686.03	687.81	688.97	689.39		
0.725		686.03	687.81	688.98	689.39		
0.73		686.14	687.66	688.47	688.69		
0.74	Downstream USH 45	686.51	688.47	689.85	690.39		
0.76	Upstream USH 45	686.93	689.10	690.55	691.09		
0.8		687.52	689.98	691.59	692.19		
0.805		688.68	690.47	691.97	692.61		
0.81		689.86	691.76	693.15	693.69		
0.8125	Canadian Pacific Railway (bridge)		- <u>-</u> .				
0.815		691.31	694.38	697.52	698.52		
0.82		691.92	694.89	697.83	698.84		
0.83		692.08	695.00	697.92	698.93		
0.94		692.75	695.44	698.20	699.20		
1.04		693.60	695.70	698.27	699.25		
1.14		694.77	696.64	698.80	699.69		
1.26		695.71	696.91	698.45	699.24		
1.27	Downstream Mayfair Road	696.11	697.80	699.39	700.10		
1.275	Upstream Mayfair Road	696.17	697.91	699.50	700.21		
1.28		696.19	697.89	699.45	700.15		
1.37		697.72	700.12	701.73	702.34		
1.45		698.35	700.90	702.51	703.11		
1.46		697.80	700.47	702.03	702.62		
1.461	Union Pacific Railroad	698.64	700.75	702.34	702.97		
1.462		700.11	702.64	704.50	705.19		

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Table	B-10	(continued)

Location		Flood Stage Elevation (feet above NGVD 1929)				
(River Mile)	Description	Two-Year	10-Year	50-Year	100-Year	
1.47		700.92	704.10	706.52	707.44	
1.49	W. Watertown Plank Road	701.27	704.34	706.69	707.58	
1.53		703.02	705.60	707.66	708.46	
1.535		702.53	705.03	707.28	708.13	
1.59		705.17	707.12	708.87	709.59	
1.595		705.17	707.04	708.83	709.57	
1.62		705.55	707.53	709.04	709.72	
1.63		705.68	707.73	709.19	709.85	
1.635		705.22	707.46	708.97	709.70	
1.69		707.80	709.15	709.79	710.28	
1.695		707.51	708.73	709.34	710.07	
1.79		709.56	711.01	711.81	711.97	
1.86		710.01	711.18	711.74	711.81	
1.87		710.03	711.10	711.47	711.41	
1.8725	N. 115th Street (bridge)			- -		
1.875		710.10	712.59	715.18	716.29	
1.88		710.24	713.04	715.84	717.01	
1.97		711.96	714.32	716.67	717.72	
2.06		712.74	714.92	717.06	718.04	
2.15		713.39	715.54	717.54	718.45	
2.19		713.67	715.79	717.72	718.61	
2.21		713.76	715.91	717.84	718.72	
2.24		713.93	716.03	717.92	718.79	
2.34		714.31	716.32	718.15	718.99	
2.42		714.46	716.36	718.17	719.01	
2.5		715.07	716.92	718.41	719.13	

^aConcrete lining removed in Wauwatosa, expanded channel cross-section in Wauwatosa, and overflow channel alternative in Elm Grove and Brookfield.