APPENDIX

D HYDRAULIC ANALYSIS

MEMO

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SUBJECT: **3216012 Hydraulic Assessment for the Woolwich Street Bridge - Salem**

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Introduction

WSP was retained by the County of Wellington to undertake the design services for the replacement of the Woolwich Street Bridge. As part of this project, a hydrologic and hydraulic assessment was completed for the existing structure and the proposed replacement structure. This memorandum outlines the required performance standards, documents design flows, and details the development of the hydrologic methodology and hydraulic model used to evaluate the existing structure and proposed replacement.

The structure is located on Woolwich Street West in the community of Salem and crosses over Irvine Creek. The structure crossing is within the jurisdiction of the Grand River Conservation Authority (GRCA).

Hydrologic Assessment

Irvine Creek flows under Woolwich from north to south. The drainage boundary contributing to the bridge is approximately 194.65 km2, which was delineated using OBM contours. The watershed consists primarily of agricultural lands with some isolated patches of treed areas and rural residential properties. According to Design Chart 1.02 of the MTO Drainage Management Manual, the site is located in Zone 1 and therefore Hurricane Hazel was used as the Regulatory Storm.

The design flows were generated using a comparison of four different methods, including:

1. The Modified Index Flood Method (MIFM)
2. Flood Frequency Analysis (FFA)
3. The Unified Ontario Flood Method (UOFM)
4. SWMHYMO, an event-based model

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The MFIM as described in the MTO Drainage Management Manual is also a regional frequency analysis method and is applicable for large watersheds. SWMHYMO is an event-based model widely used to determine runoff characteristics for rural and urban watersheds. This model was also used to generate the peak flow resulting from the Hazel (Regional) Storm event.

The FFA uses the GRCA's FFA fitted curve and is referenced to the Irvine River at Salem which has a drainage area of 174 km^2.

The UOFM has been developed for the calculation of the design flow rates in Ontario by MTO. The design flows represent the peak flow estimates (flood quantiles) of various return periods for bridges and culverts, at stream and river crossings. This method uses mean annual precipitation, drainage area and lake attenuation index to generate peak flows.

The SCS 12-hour, AES 12-hour and SCS 24-hour storm distributions were used to determine the flows at the crossing using SWMHYMO modelling. These storm distributions represent long duration, high volume rainfall events. The parameters used in the hydrologic modelling include the Curve Number (CN), Initial Abstraction (I_a), and the Time to Peak (T_p). The SCS Upland Method, SCS Curve Number Method and the Airport Method were used and the results averaged to calculate the T_p. For the catchment, modelling parameters were selected based on soil type, land use and topography. The parameters were then calibrated to the hydrologic method selected for the analysis to determine the Regional flow.

The summary of peak flows is summarized in **Table 1**. As the flows in HEC-RAS model provided by GRCA yielded the highest flows, it was carried forward in the analysis. The FFA flows may, however, be significantly conservative (especially the Regional storm) and result in more deficiencies than would otherwise be reasonable.

Table 1 Peak Flow Comparison

Calculation Method	Return Period Flow (m^3/s)						
	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	Regional
FFA	94	137	184	245	292	339	-
SWMHYMO	85	146	175	248	293	339	967
MIFM	75	98	120	147	166	186	-
UOFM	62	-	114	142	164	187	-
OFAT	51	79	101	134	162	193	-

*This value is calibrated

Hydraulic Criteria

The following hydrologic and hydraulic performance standards were identified to evaluate the performance of the existing structure as well as proposed replacement and temporary works options:

- Design storms used to calculate flood elevations
- Minimum and desired top of road freeboard
- Minimum soffit clearance
- Maximum depth of relief flow over the road
- Maximum product of depth and velocity of relief flow over the road
- Allowable increase in flood elevation upstream of the structure
- Temporary works during construction

The replacement of the Woolwich Street structure is not a Ministry of Transportation (MTO) project; however, the performance standards used in this study are based on the MTO Highway Drainage Design Standards (HDDS) (January 2008). The MTO standards were used since they incorporate much of the standards for watercourse crossings from the Canadian Highway Bridge Design Code. Table **Table 2** provides a summary of the MTO Drainage Design Standards applied to this assessment.

Table 2 MTO Drainage Design Standards

Item	Design Standard	Description	Standard	Section
1	Design Flow Storm	50-Year	WC-1	1.1.1
2	Top of Road Freeboard (Min.)	>1.0 m (Design Flow Water Surface Elevation – top of road low point)	WC-7	3.1.2
3	Top of Road Freeboard (Desired)	>1.0 m (Design Flow Energy Grade Line Elevation – top of road low point)	WC-7	3.1.1
4	Relief Flow (Max. Depth over roadway)	Max. depth over roadway should not exceed 0.3 m for Regulatory Storm	WC-13	3.2.1
5	Relief Flow (Velocity x Depth)	Velocity x Depth should not exceed 0.8 m^2/s for Regulatory Storm	WC-13	3.2.2
6	Soffit Clearance	Design Flow Water Surface Elevation – Soffit Elevation ≥1.0 m	WC-2	3.2.1

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Existing Conditions Hydraulics

The 2-year through 100-year as well as the Regulatory Storm events were analysed in HEC-RAS; the 50-year storm event is the design storm for the structure replacement. The existing top of road freeboard, flood depth, and other hydraulic performance parameters as they pertain to the MTO HDDS are identified in **Table 3**. **Table 4** illustrates whether the existing structure meets current hydraulic standards.

Table 3 Top of Road and Soffit Clearance Summary – Existing Conditions

Description	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	Regional
Water Surface Elevation	387.85	388.37	388.85	389.35	389.68	390.00	393.24
Energy Grade Line Elevation	387.88	388.42	388.92	389.45	389.81	390.15	393.48
Top of Road (Low Point)	390.32						
(2+4) Top of Road Freeboard (Min.)	2.47	1.95	1.47	0.97	0.64	0.32	-2.92
(3) Top of Road Freeboard (Desired)	2.44	1.90	1.40	0.87	0.51	0.17	-3.16
Top of Road Velocity	-	-	-	-	-	-	1.37
(5) Top of Road Velocity x Depth	-	-	-	-	-	-	4.00
Soffit Elevation (Upstream)	389.69						
(6) Soffit Clearance	1.84	1.32	0.84	0.34	0.01	-0.31	-3.55

Table 4 Hydraulic Performance Summary – Existing Conditions

Criteria Description	Criteria Storm Event	Meets Criteria (Yes or No)
(2) Top of Road Freeboard (Min.)	50-Year	No
(3) Top of Road Freeboard (Desired)	50-Year	No
(4) Relief Flow (Max. Depth over roadway)	Regional	No
(5) Relief Flow (Velocity x Depth)	Regional	No
(6) Soffit Clearance	50-Year	No

As shown in **Table 4**, the existing bridge fails to meet any of the hydraulic criteria.

Proposed Conditions Hydraulics

The following alternatives were developed for the replacement of the existing bridge:

1. Option 1: A single 36 m span with 1600mm CPCI girder
2. Option 2: A single 36 m spam with 1400 mm NU girder

The Alternative 1 top of road freeboard, flood depth, and other hydraulic performance parameters as they pertain to the MTO HDDS are identified in **Table 5**. **Table 6** illustrates whether the Alternative 1 structure meets current hydraulic standards.

The Alternative 2 top of road freeboard, flood depth, and other hydraulic performance parameters as they pertain to the MTO HDDS are identified in **Table 7**. **Table 8** illustrates whether the Alternative 2 structure meets current hydraulic standards.

Both of the bridge alternatives are very similar in hydraulic performance to the existing conditions. Performance is increased for smaller flows owing to the larger span, but as waters rise, the lower proposed soffit elevation becomes a constriction.

Both proposed soffit clearances are proposed to be reduced. This situation is not ideal, but the bridge is quite constrained due to the surrounding fixed infrastructure. Without significantly modifying the nearby roadways, the top of roadway cannot be significantly raised and therefore the soffit elevation cannot be significantly raised. In both alternatives, however, the Regional flood elevation is not significantly increased.

It is worth noting again that the FFA flows used for the analysis may be significantly conservative (especially the Regional storm) and result in more deficiencies than would otherwise be reasonable. With lower flows, the proposed bridges have a significant increase in hydraulic performance. During larger flows, the hydraulic performance equivalent to the existing structure.

Table 5 Top of Road and Soffit Clearance Summary Option 1-1600 mm CPCI girder

Description	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	Regional
Water Surface Elevation	387.85	388.37	388.85	389.36	389.71	390.04	393.25
Energy Grade Line Elevation	387.87	388.41	388.92	389.45	389.83	390.19	393.49
Top of Road (Low Point)	390.32						
(2+4) Top of Road Freeboard (Min.)	2.47	1.95	1.47	0.96	0.61	0.28	-2.93

Description	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	Regional
(3) Top of Road Freeboard (Desired)	2.45	1.91	1.40	0.87	0.49	0.13	-3.17
Top of Road Velocity	-	-	-	-	-	-	1.47
(5) Top of Road Velocity x Depth	-	-	-	-	-	-	4.31
Soffit Elevation (Upstream)	388.77						
(6) Soffit Clearance	0.92	0.40	-0.08	-0.59	-0.94	-1.27	-4.48
(7) Max. Increase upstream of structure	0.00	0.00	0.00	0.01	0.03	0.04	0.01

Table 6 Hydraulic Performance Summary Option 1-1600 mm CPCI girder

Criteria Description	Criteria Storm Event	Meets Criteria (Yes or No)
(2) Top of Road Freeboard (Min.)	50-Year	No
(3) Top of Road Freeboard (Desired)	50-Year	No
(4) Relief Flow (Max. Depth over roadway)	Regional	No
(5) Relief Flow (Velocity x Depth)	Regional	No
(6) Soffit Clearance	50-Year	No
(7) Max. Increase upstream of structure	Regional	Yes

Table 7 Top of Road and Soffit Clearance Summary Option 2-1400 mm NU girder

Description	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	Regional
Water Surface Elevation	387.85	388.37	388.85	389.35	389.70	390.03	393.24
Energy Grade Line Elevation	387.87	388.41	388.92	389.45	389.82	390.17	393.49
Top of Road (Low Point)	390.32						
(2+4) Top of Road Freeboard (Min.)	2.47	1.95	1.47	0.97	0.62	0.29	-2.92
(3) Top of Road Freeboard (Desired)	2.45	1.91	1.40	0.87	0.50	0.15	-3.17
Top of Road Velocity	-	-	-	-	-	-	1.44
(5) Top of Road Velocity x Depth	-	-	-	-	-	-	4.22
Soffit Elevation (Upstream)	388.97						
(6) Soffit Clearance	1.12	0.60	0.12	-0.38	-0.73	-1.06	-4.27
(7) Max. Increase upstream of structure	0.00	0.00	0.00	0.01	0.02	0.03	0.00

Table 8 Hydraulic Performance Summary Option 2-1400 NU girder

Criteria Description	Criteria Storm Event	Meets Criteria (Yes or No)
(2) Top of Road Freeboard (Min.)	50-Year	No
(3) Top of Road Freeboard (Desired)	50-Year	No
(4) Relief Flow (Max. Depth over roadway)	Regional	No
(5) Relief Flow (Velocity x Depth)	Regional	No
(6) Soffit Clearance	50-Year	No
(7) Max. Increase upstream of structure	Regional	Yes