TECHNICAL MEMORANDUM

TO:	Steve Taylor, P.Eng.	**OUR REF.:**	SN0461
FROM:	Leonardo Sanchez, P.Eng.	**DATE:**	June 11, 2024 Revised July 30, 2024

COPY: Darcie Dillon, P.Eng., Daniela Hurtado Caicedo, M.Sc.

RE: **Stormont, Dundas & Glengarry Counties Road 22 Rehabilitation, Culvert Replacement Recommendations**

This Technical Memorandum updates the one dated April 5, 2023, and updated on March 15 and June 11, 2024, to reflect the additional culverts at Stations 15+300 and 15+690, based on comments provided by the County.

1 Introduction

BT Engineering was retained by the United Counties of Stormont, Dundas and Glengarry (SDG) to complete the design for the reconstruction of County Road 22 (CR 22) from Highway 138 to Roxborough Kenyon Boundary Road. The design includes the relocation of the municipal drains in the segments where CR 22 will be widened.

A Technical Memorandum was provided on November 14, 2022, providing the recommended sizes for the proposed replacement transverse culverts. This memorandum supersedes and expands on the previous one by providing the design flows for the culverts and confirmation of the culvert replacement recommendations.

2 Design Criteria

CR 22 is considered a minor arterial link between Highway 138 and the Village of Maxville. The annual average daily traffic ranges from 1,223 at the west end to 1,267 at the east end.

2.1 Municipal Drains

The municipal drains will be relocated with minor adjustments to their section and grade. Therefore, their hydraulic capacity will be equal to or greater than the original design in their respective Drainage Reports. Details of the hydraulic analysis and final design were prepared by BTE, as reported by them on July 30, 2024.

2.2 Culvert Design Criteria

Culverts will be replaced based on their condition, as described in the BTE memorandum *Inspection of County Road 22 Culverts and Associated Fish Habitat*. The replacement culverts will be HDPE culverts, except that culverts greater than 2.4 m diameter will be replaced with precast box culverts.

The MTO *Highway Drainage Design Standards* provides the design criteria for culvert hydraulic design and for watercourses along a road.

Standard WC-1 – Design Flows (Bridges and Culverts) provides that culverts with span less than 6.0 m shall be designed to convey the 25-year flood.

Standard WC-7 – Culvert Crossings on a Watercourse states that the Freeboard design standard for arterial roads is a minimum of 1.0 m. The standard recognizes that it may not be possible to achieve the required Freeboard and/or Clearance in some retrofit applications.

3 Design Flows

The drainage areas to the culverts are shown on the attached Drainage Area Plan, included at the back of this memorandum.

Design flows were estimated using three alternative methods:

a. UOFM - MTO Unified Ontario Flood Method, per Highway Standards Branch, Provincial Engineering Memorandum, Design and Contracts Standards Office #2016-03, March 31, 2016.
b. Index Method - Regional Flood Frequency Analysis for Ontario Streams, Volume 1, Single Station Analysis and Index Method, Canada/Ontario Flood Damage Reduction Program, S. Moin & M. Shaw, 1985.
c. HEC-HMS model of the watersheds.

A comparison of the resulting flood estimates is presented in Table 1. As can be observed, the largest peak flows were estimated using the MTO Unified Ontario Flood Method. The flows calculated using the Index Flood Method are significantly lower, and the flows calculated using the HEC-HMS models are very low.

Table 1 - Design Flood (25-year return period) by alternative methods

Culvert No.	Drainage Area (ha)	Estimated Design Flood flow Q_{25} (m^3/s)		
		UOFM	Index Flood Method	HEC-HMS
1	68.5	2.14	0.65	0.13
2	282.9	6.02	2.33	0.24
3	8.0	0.45	0.10	0.05
5	2.0	0.16	0.03	0.10
6	401.6	7.77	3.19	0.75
7	2.0	0.16	0.03	0.01
8	7.6	0.43	0.09	0.13

Table 1 - Design Flood (25-year return period) by alternative methods				
Culvert No.	Drainage Area (ha)	Estimated Design Flood flow Q_{25} (m^3/s)		
		UOFM	Index Flood Method	HEC-HMS
9	59.6	1.94	0.58	0.13
10	142.9	3.66	1.26	1.10
11	20.0	0.88	0.22	0.26

In selecting the design flood for each crossing, it is necessary to consider that the three methods provide estimates of the flood flow associated with each return period (the inverse of the annual probability that the flood will be equaled or exceeded in any one year). The UOFM and the Index Method are based on statistical analysis of recorded flows, undertaken on a regional basis, which means that the methods are applicable within the range of watershed drainage areas and flows used to estimate the probability distributions and the regression equations. In the case of the small watersheds in the study area, it was found that they are outside of the ranges for both UOFM and the Index Method. The HEC-HMS method may introduce more uncertainty into the results, since it is based on models of the unit hydrographs, the rainfall-runoff relations, and the rainfall distributions, all of which are based on approximations.

To help determine which flood estimates are most appropriate for this project, the Unit Flow for each watershed was calculated, defined as the ratio of the total flood estimated divided by the drainage area. The units for the Unit Flows are $m^3/s/km^2$. The results of the calculation of the unit flow per square kilometer produced by each watershed for each method is shown on Table 2.

Table 2 - Unit Flows (Design Flood/Drainage Area)			
Culvert No.	Unit Flow (Design Flood/Drainage Area) ($m^3/s/km^2$)		
	UOFM	Index Flood Method	HEC-HMS
1	3.13	0.95	0.19
2	2.13	0.82	0.08
3	5.61	1.19	0.63
5	8.18	1.38	5.00
6	1.93	0.79	0.19
7	8.17	1.38	0.50
8	5.69	1.20	1.72
9	3.25	0.97	0.22
10	2.56	0.88	0.77
11	4.37	1.09	1.30

It can be observed that the values produced by the UOFM in this case are very high. Generally, it is expected that the unit flow for the 25 year flood will be around 1.0 $m^3/s/km^2$. Review of the average unit flows and their standard deviation, as shown on Table 3, indicates that in this case the Index Flood Method results are the more stable of the three estimates. This is reflected in the standard deviation of the unit flow.

Table 3 - Unit Flow Average and Standard Deviation			
Parameter	**UOFM**	**Index Flood Method**	**HEC-HMS**
Average Unit Flow ($m^3/s/km^2$)	4.20	1.03	2.66
Standard Deviation ($m^3/s/km^2$)	2.43	0.24	5.49

Based on these results, it can be concluded that the Index Flood Method provides the best estimates of the design floods for this project.

To further confirm the results, the relation between drainage area and the Mean Annual Flood (2.33 year return period) published in *Flood Flow Statistics for the Great Lakes Watershed System, Ontario, 2014* was used to calculate the Mean Annual Flood for the watersheds.

$$MAF = Q_{2.33} = 0.8753(Drainage\ Area)^{0.7072}$$

The results are presented in Table 4. The Mean Annual Flood was converted to the Design Flood (25 year return period) using the ratio between the 2 year flood and the 25 year flood contained in the Moin and Shaw 1985 publication. The resulting estimates of the 25-year flood for each watershed are also presented in Table 4.

Table 4 - Mean Annual Flood and Design Flood Estimate based on Ontario Flood Statistics			
Culvert No.	**Mean Annual Flood (m^3/s)**	**$Q_{25}/Q_{2.33}$**	**Q_{25} (m^3/s)**
1	0.67	1.8	1.21
2	1.83	1.8	3.29
3	0.15	1.8	0.26
5	0.06	1.8	0.10
6	2.34	1.8	4.21
7	0.06	1.8	0.10
8	0.14	1.8	0.25
9	0.61	1.8	1.09
10	1.13	1.8	2.03
11	0.28	1.8	0.51

Comparison of the flood estimates in Tables 2 and 4 confirms that in most cases the Index Flood

Method provides a realistic estimate of the design floods for the study watersheds. Accordingly, the Design Flood values used to design the culverts are presented in Table 5. It is noted that Culvert 4 was not part of this analysis, as it will not be replaced or enlarged.

Table 5 - Design Flood Flows

Culvert No.	Drainage Area (ha)	Design Flood (m^3/s)
1	68.5	0.65
2	282.9	2.33
3	8.0	0.10
5	2.0	0.03
6	401.6	3.19
7	2.0	0.03
8	7.6	0.09
9	59.6	0.58
10	142.9	1.26
11	20.0	0.22

4 Replacement Culverts

Table 6 summarizes the existing culverts to be replaced and the recommended culvert types and sizes. The culverts can be placed at the same invert elevations as the existing, except for culverts 3 and 5, which should be set with inverts matching the approach and leaving channels, to avoid scour at the outlet due to the perched outlets. In addition, Culvert 3 should be upsized to reduce the barrel velocities.

Table 6 - Replacement Culverts

Culvert Number	Existing Culvert		Proposed Culvert	
	Type	Diameter (mm)	Type	Diameter [Span x Rise(mm)
1	CSP	600	HDPE	900[a]
2	CSP	1500	Aluminized Type 2 Steel CSP	1600
3	CSP	500	HDPE	600
5	UltraFlo™ CSP	600	HDPE	600
6	CSP	1600	Aluminized Type 2 Steel CSP	1600
7	CSP	600	HDPE	600
8	CSP	600	HDPE	600
9	Twin CSP	1600	CBC	1200 x 1200[b]
10			HDPE	900
11	CSP	800	HDPE	800

CSP = Corrugated Steel Pipe; HDPE = High Density Polyethylene; CBC = Concrete Box Culvert

[a] This culvert is owned by MTO, and it should be upsized to accommodate the 25-year design storm flow. It is not in the contract because it is not owned by the Counties.

[b] Culvert 9 could be replaced with Twin Aluminized Type 2 Steel 1600 mm diameter CSP pipes, equal to the existing culvert.

Appropriate scour and erosion protections must be provided at the inlet and outlet of each culvert. Rip-rap scour protection for all culverts is shown on the drawings.

Table 7 presents the headwater level, ratio of headwater depth to rise of the culvert (HW/D), and freeboard for each culvert.

Table 7 - Headwater Level, Freeboard & HW/D

Culvert No.	Station	Headwater Level (m)	Freeboard (m)	HW/D
1	10+015	N/A	N/A	N/A
2	11+730	82.71	1.61	0.68
3	12+320	83.84	1.36	0.48
5	13+278	78.24	2.56	0.48
6	14+415	78.37	1.91	0.97
7	14+703	78.40	1.90	0.26
8	14+909	78.76	2.04	0.53
9	14+976	78.84	2.16	0.38
10	15+300	82.85	0.95	0.96
11	15+690	88.20	0.80	0.59

5 Conclusions

Based on their condition, a total of eight culverts will be replaced. CSP culverts with diameters up to 900 mm will be replaced with HDPE pipe.

Culverts with diameter greater than 900 mm can be replaced with aluminized Type 2 steel CSP culverts.

Culvert 9 can be replaced with a concrete box culvert with equal or greater hydraulic capacity than the existing or with aluminized Type 2 steel CSP culverts of the same diameter as existing.

6 Recommendations

It is recommended that the culverts be replaced in accordance with the sizes given in Table 6. The culvert inverts should match the existing inverts, except at culverts 3 and 5, where they should be modified to match the inverts of the approach and leaving channels.

Prepared by

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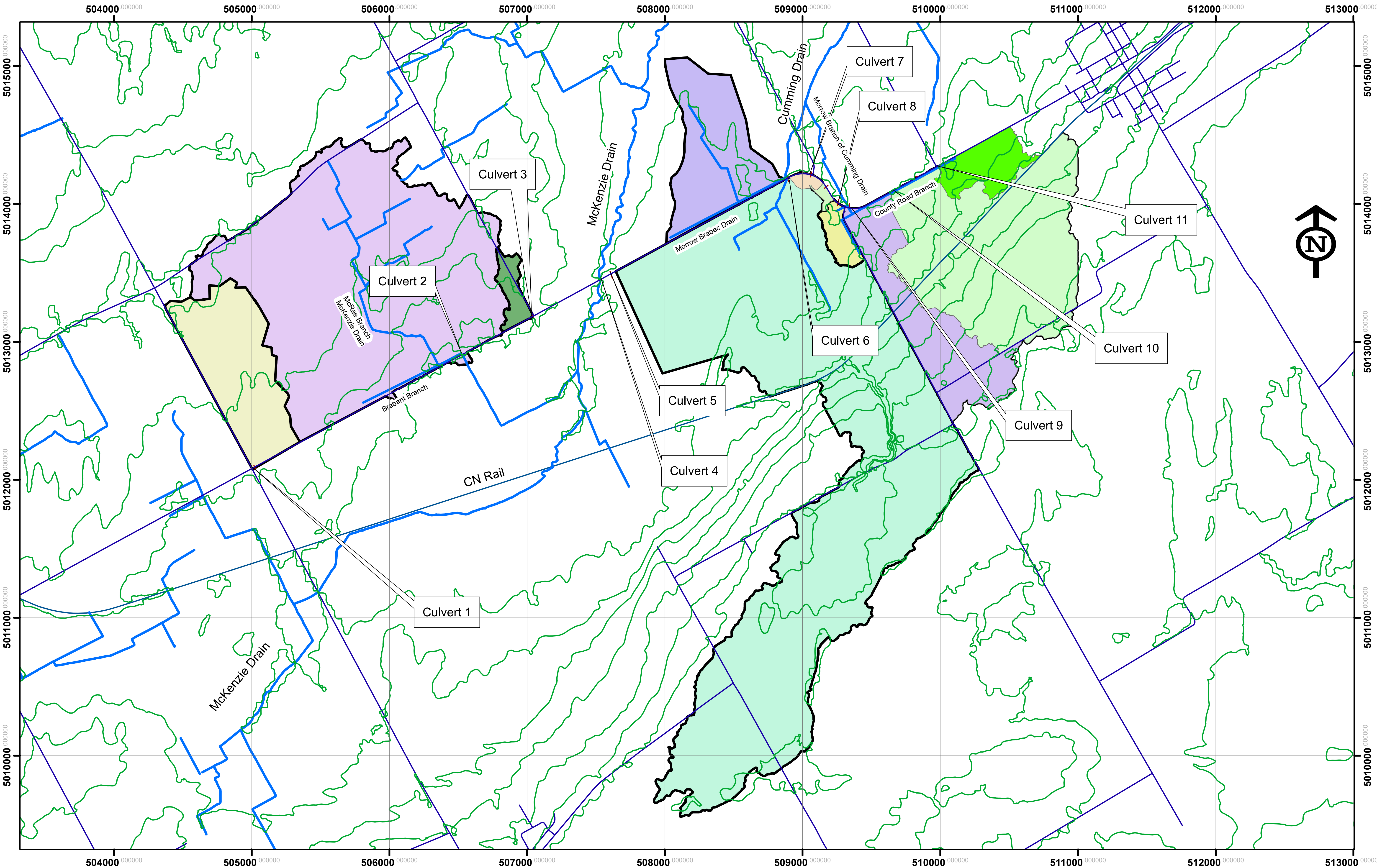
REGISTERED PROFESSIONAL ENGINEER
L. SANCHEZ
July 30, 2024
PROVINCE OF ONTARIO



Sanchez Engineering Inc.

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UC SDG CR 22
DRAINAGE AREAS TO CULVERTS