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BRITANNIA ROAD TRANSPORTATION CORRIDOR IMPROVEMENTS: TREMAINE ROAD TO HIGHWAY 407 CLASS EA STUDY

ENVIRONMENTAL STUDY REPORT – FLUVIAL GEOMORPHOLOGY STUDY

A Report Submitted by:

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Table of Contents

1.0 Introduction

1.1 Overview of Study

The completion of a Class Environmental Assessment Study for the Britannia Road (Regional Road 6) Transportation Corridor Improvement will identify existing conditions and potential impacts from the proposed road widening of Britannia Road on the natural environment. The Environmental Assessment Study considered five (5) transportation corridor improvement alternatives for Britannia Road which included a “do nothing” alternative and four (4) widening alternatives. The widening alternatives varied according to the location of the widening, including: widen to the north of the existing right-of-way; widen to the south; widen about the centerline; or a combination of these widening locations. The later alternative was selected through a separate screening exercise and consists of widening to either the north, south or about the centerline, depending on the location along the corridor. This selected alternative is referred to as Alternative 5.

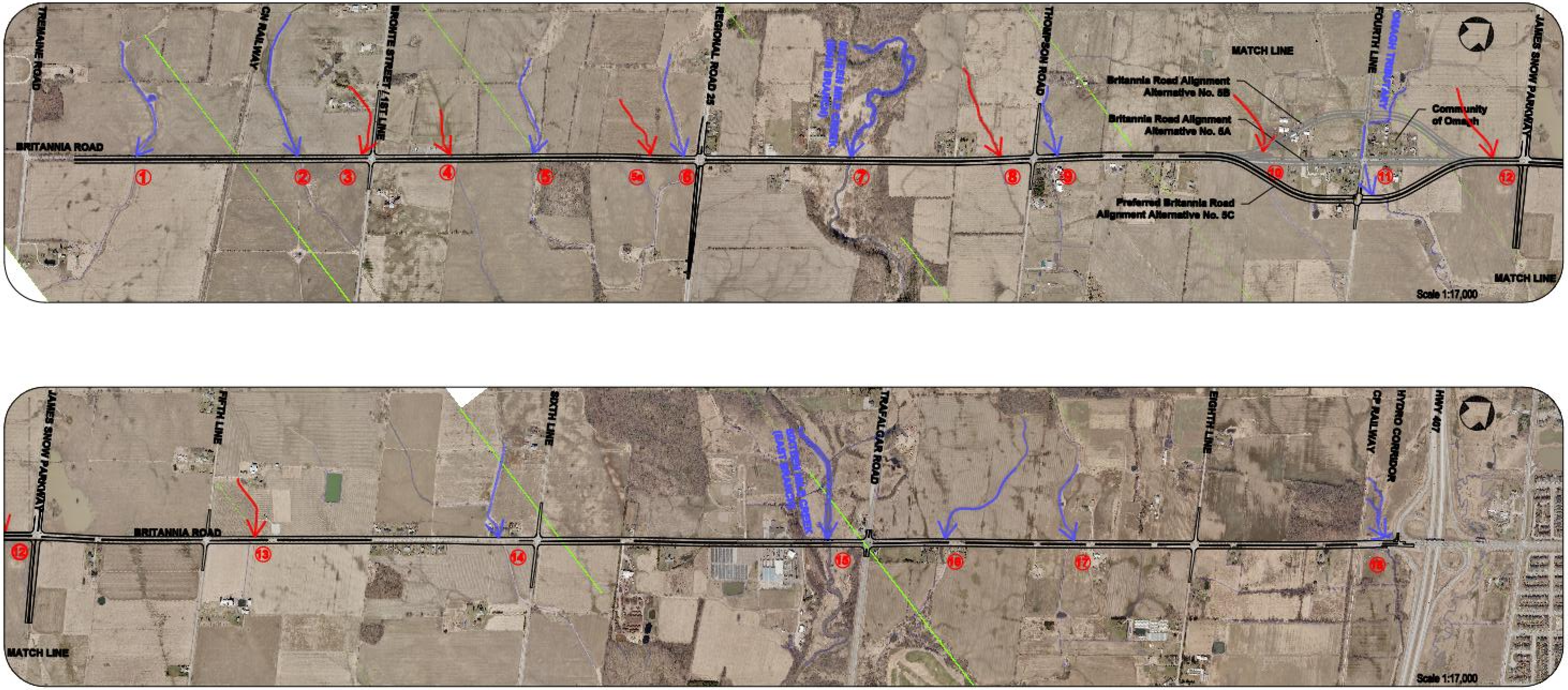
For the selected alternative, three (3) alignment options were considered for how Britannia Road will pass through the community of Omagh, located at the intersection of Britannia Road and Fourth Line.

1. Alternative 5A - widening along the existing alignment, through the community of Omagh;
2. Alternative 5B – construction of a new road to by-pass Omagh to the north; or
3. Alternative 5C – construction of a new road to by-pass Omagh to the south.

The following geomorphic assessment focuses specifically on watercourse form and function and identifies the existing physical characteristics at each crossing to determine the possible influences of culvert extensions, flow capacity increases, and realignments on channel stability. Documentation of existing conditions was completed through site inspections by Aquafor Beech Limited at 19 crossings along Britannia Road on various days in 2010 and 2011. Identification of existing conditions and the subsequent analysis will form the basis for assessing design alternatives, and specifically the preferred alternative 5C, for the crossings within the study area.

1.2 Background

Britannia Road is within the jurisdiction of the Halton Region and is a major east-west 2 lane rural arterial roadway. The study area extends from Tremaine Road to Highway 407 and is approximately 12.5 km long (**Figure 1**). The watercourses within the study area are part of the Sixteen Mile Creek watershed and the Indian Creek watershed (which is a tributary of the Bronte Creek watershed). The study area includes crossings of 19 watercourses, 3 are within the Indian Creek watershed and the remainder are within the Sixteen Mile Creek watershed (**Table 1**). The Sixteen Mile Creek watershed is further divided into Subwatershed areas 2 and 7, as well as the East-Lisgar Branch Subwatershed. Watercourses at Crossings 4 to 9 are within Subwatershed 2, watercourses at Crossings 10 to 15 are



LEGEND

- CROSSING No.
- REGULATED STREAM
- UNREGULATED DRAINAGE FEATURE

FIGURE 1. STUDY AREA STREAM CROSSINGS

BRITANNIA ROAD TRANSPORTATION CORRIDOR IMPROVEMENTS

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within subwatershed 7, and the remainder of Crossings 16 to 18 are within the East-Lisgar Subwatershed. The 17 smaller tributaries of Sixteen Mile and Indian creeks are ephemeral or intermittent watercourses that go dry during the summer months and contain a fine substrate material of mostly silt, clay, and organics. The main branches are permanent watercourses that flow continuously and contain larger particle sizes of cobble and gravel along the bed.

Fieldwork completed by Philips Engineering Ltd (2000) did not reveal many areas of excessive erosion. The Indian Creek watershed has a moderate topography due to the Niagara Escarpment in the upstream reaches (Philips Engineering Ltd, 2004). The drainage density of 16 Mile Creek subwatershed area 2 and the Indian Creek watershed are due to subsurface drains replacing natural surface channels (Philips Engineering Ltd, 2000) and artificial drainage such as agricultural tile drains (Philips Engineering Ltd, 2004). The dominant land-use within both watersheds is agricultural and historical analysis identified that very little change has occurred over time, with only a slight increase in residential housing (Philips Engineering Ltd, 2000, 2004).

Table 1: Inventory of existing watercourse crossings for Britannia Road within study area.

Crossing #	Station	Existing Structure[1]	Watershed (Branch)	Tributary (Subwatershed)	Pending Develop.	CA Regulation
1	0 + 673	Concrete Box	Bronte	Indian Ck.	Boyne	Regulated
2	1 + 360	Steel Pipe Arch	Bronte	Indian Ck.	Boyne	Regulated
3	1 + 560	Conc. Open Foot.	Bronte	Indian Ck.	Boyne	Regulated[3]
4	2 + 000	C.S.P.	Sixteen Mile (Main)	West Trib. (2)	Boyne	Unregulated
5	2 + 430	Conc. Open Foot.	Sixteen Mile (Main)	West Trib. (2)	Boyne	Regulated
5a	2 + 800	(C.S.P)[2]	Sixteen Mile (Main)	West Trib. (2)	Boyne	Unregulated
6	2 + 964	(C.P.E. [x2])[2]	Sixteen Mile (Main)	West Trib. (2)	Boyne	Regulated
7	3 + 660	Bridge	Sixteen Mile Creek Main Branch	Main Branch (2)	Boyne	Regulated
8	4 + 300	C.S.P.	Sixteen Mile (Main)	East Trib. (2)	Boyne	Regulated[3]
9	4 + 525	Concrete Box	Sixteen Mile (Main)	East Trib. (2)	Boyne	Regulated
10	5 + 371	Concrete Pipe	Sixteen Mile (East)	Trib. (7)	Boyne	Unregulated
11	5 + 823	Conc. Open Foot.	Sixteen Mile (East)	Omagh Trib. (7)	Boyne	Regulated
12	6 + 472	C.S.P.	Sixteen Mile (East)	Omagh Trib. (7)	Boyne	Unregulated
13	7 + 500	C.S.P.	Sixteen Mile (East)	Trib. (7)	-	Unregulated
14	8 + 540	Conc. Open Foot.	Sixteen Mile (East)	Trib. (7)	-	Regulated
15	9 + 880	Bridge	Sixteen Mile Creek East Branch	East Branch (7)	-	Regulated
16	10 + 400	C.S.P.	Sixteen Mile (East)	East-Lisgar Tribs.	-	Regulated[3]
17	10 + 900	C.S.P.	Sixteen Mile (East)	East-Lisgar Tribs.	-	Regulated
18	12 + 182	Concrete Box [x2]	Sixteen Mile (East)	East-Lisgar Tribs.	-	Regulated

Notes:

1. C.S.P = Corrugated steel pipe; C.P.E. = Corrugated polyethylene pipe
2. Two culverts were replaced during EA study with upgrades at Hwy 25 intersection, including Crossing 5a (diverted to ditch drainage) and Crossing 6 (Concrete Box [x2]).
3. Regulated on south side of Britannia Road, so CA permitting will be required for culvert replacement.

2.0 Methodology

In order to document the existing conditions at each crossing and assess the influences of proposed road widening on channel processes, a number of approaches were applied. These included field assessments and basic stability analyses to demonstrate that hydraulic changes resulting from the proposed culverts will not increase risks of channel instability. In addition, a planning framework was developed to make culvert alignment recommendations for the proposed culverts based on consideration of culvert length, channel realignments, and construction issues. The geomorphic assessment results were used to make recommendations with respect to culvert and bridge designs, including bankfull width criteria for crossing spans, which were subsequently applied to the hydraulic modeling to iteratively arrive at the proposed culvert specifications.

2.1 Field Assessments

A synoptic level field assessment was designed to document the existing channel processes at each crossing in order to interpret channel form and function. The field assessment took into consideration the surrounding floodplain, riparian bank vegetation, boundary materials, channel planform, and interpreted flow characteristics to identify the current geomorphic condition of the watercourse.

More detailed field assessments were also conducted at each crossing to define the basic channel geometric parameters and substrate characteristics. The following data was collected at each accessible site: bankfull width, bankfull depth, bed material composition, and photographic documentation. Channel elevation profiles were also reviewed based on the detailed topographic survey data obtained from Delcan Corporation.

2.2 Stability Analysis

The stability analysis considers the potential for erosion to occur within the watercourse and is defined as the streams ability to entrain boundary materials in terms of approximate thresholds given as a permissible range (Fischenich, 2001). The stability analysis was completed for all 19 crossings to demonstrate that hydraulic changes resulting from the proposed culverts will not increase risks of channel instability.

Specifically, the stability analysis used flow velocity and average boundary shear stress results for both existing and proposed conditions based on multiple iterations of the hydraulic analysis (completed using HEC-RAS and HY-8). Average cross-sectional velocities were used to assess the local boundary stability in the channel at each crossing, whereas, average boundary shear stress was used to assess reach-scale channel stability in the vicinity of the crossing. The aim of the stability assessment was to demonstrate a relative decreases in both the proposed velocities and shear stresses compared to existing conditions, as well as to minimize absolute exceedances of permissible values (Fischenich, 2001).

2.3 Culvert Alignment Recommendations

A planning framework was suggested by the technical EA project team for culvert alignment recommendations at the Britannia Road EA stage to allow for consideration of alignment impacts to the natural environment and to road construction in advance of detailed design. A strong preference for culvert alignments perpendicular to the road (i.e., 90^o) was indicated by Conservation Halton to minimize the culvert lengths and consequent impacts to aquatic habitat, in terms of enclosure lengths and fish passage concerns in particular. The basic approach was to consider four primary culvert alignments which were drafted as three options for channel realignment required for perpendicular culverts, as well as one option of a longer culvert length oblique to the road which would minimize channel realignments.

3.0 Existing Conditions

3.1 Field Assessments

Documentation of existing conditions for each watercourse was collected at both the upstream and downstream sides of the crossing. This field assessment identified the existing channel form and function to provide information on channel stability and erosion potential. This data was used as a guide for management objectives and restoration opportunities associated with lengthening of the existing culverts.

Existing conditions for each of the watercourses is summarized in **Table 2** with respect to adjacent landuse, valley setting, channel form, and other defining characteristics of flow and boundary type. As documented in previous studies, the dominant landuse within the study area is currently agricultural with local rural residential lots; however, plans for future development are underway on the north side of Britannia Road between Tremaine Road and James Snow Parkway (i.e., Boyne Survey). Most of the watercourse and drainage features within the study area are relatively small, with drainage areas typically less than 2 – 3 km^2. The primary exceptions being the Sixteen Mile Creek Main Branch and East Branch (Crossings 7 and 15 respectively) which drain in the range of 125 – 150 km^2.

As is typical of most low-relief headwater features in southern Ontario, the smaller watercourses are not situated within any defined valley landform, but in some cases gradual side-slopes do dip toward a topographic low associated with the watercourse or drainage feature. The primary exceptions are Crossing 7 and 15 (Main and East Branches of Sixteen Mile Creek) which are each situated within well defined valley landforms incised 15-20 m below the surrounding uplands. Crossing 11 (Omagh Trib.) is also situated within a defined valley landform about 5 m below upland elevations. None of the watercourses or drainage features were considered to be entrenched during field assessments, and thus all watercourse were interpreted to have good floodplain connectivity (however, artificial drainage ditches may be somewhat "entrenched" by design).

All small watercourses (17 of 19) were inferred to be dominantly ephemeral channels, with areas of prolonged intermittent surface flow in some cases. Seven drainage features of the 19 were considered to be completely ephemeral (**Table 2**). As is typical of ephemeral channels in the region, all small watercourses were considered to be vegetation-dominated in terms of morphological processes, whereby vegetated surfaces on the bed and banks restrict the more predictable processes of sediment entrainment and transport. Such headwater channel forms are typically broad swale-like features (or ditches) with poorly defined channel banks and relatively disorganized and opportunistic low-flow patterns. Further, the upland surface geology is dominated by silt and clay (from glacial till and glaciolacustrine sequences; OGS, 1997), with very few sources of coarse grained material. The lack of gravel and cobble bed materials (and thus bedload transport processes) does not typically allow for the formation of regular bed morphologies (e.g., riffle-pool sequences) or alluvial bar formations. Vegetation types within the small watercourses were typically classified as long or short native grasses, turf, and cattails (and other herbaceous cover, and some local tress/shrubs), and were the basis for permissible velocity and shear stress recommendations in the stability analysis (after Fischenich, 2001).

The Main and East Branches of Sixteen Mile Creek were the only two watercourses which were classified as well defined channels with perennial flow regimes. These larger watercourses within incised valleys are characterized by cobble and gravel bed materials, and thus exhibit the expected processes of fluvial bedload transport, planform meandering, and bed morphology development (i.e., shear-dominated channels). As such, the average velocity and shear stress entrainment thresholds for gravel and cobble sized bed materials were the basis of permissible recommendations in the stability analysis (after Fischenich, 2001). Riparian vegetation types within the valley were variable from native grasses to naturalized areas of trees and shrubs (see Terrestrial section of Environmental Study Report for further details).

Minor evidence of local erosion during the field assessment was primarily interpreted to be due to agricultural or local construction activities; livestock disturbances; low-flow avulsions and slumping within vegetation-dominated swales; and bare soil on ditch embankments. Within the larger perennial watercourses, natural processes of cutbank erosion were also evident. Backwater effects within the culverts were observed in 12 of the 19 watercourse crossings along Britannia Road typically due to in-channel vegetation and other obstructions downstream; undersized culverts, or online ponds.

An additional consideration during the field assessment was the location of roadside ditch features contributing to watercourse flows on both the north and south sides of the existing roadway (**Table 2**). These features should be considered during the detailed design stage to ensure that positive drainage is maintained towards the watercourses alongside the new road (or may be integrated into storm sewer system). There are also a number of areas where internal drainage does not directly outlet to existing watercourses (e.g., including but not limited to areas between Crossings 12 and 14; Crossings 14 and 15; and Crossings 17 and 18). In some cases, the existing ditches may have small equalizer culverts crossing under the road. Options to maintain positive drainage in these areas due to road widening might include reinstatement of local roadside ditches and swales, equalizer culverts, and/or collection/integration of flows into the new storm water drainage system for Britannia Road.

Detailed field assessments along the watercourses allowed for documentation of geometric properties and substrate characteristics, as well as a photographic inventory (**Appendix A**). Channel bankfull width and depth measurements were conducted at two sites upstream and downstream at each crossing where access was granted to the channel (**Table 3**). Three of the 19 crossings have no measurements taken along the watercourse due to either no accessibility or, as in the case for Crossing 13, the channel would be classified as a roadside ditch. In the case of all small ephemeral and intermittent watercourses (with drainage areas typicaly less than 2 – 3 km^2), the term bankfull is used here to loosely represent a defined frequent flow channel which may or may not be associated morphologically with annual flood conditions or ~2 year flood frequencies. On the other hand, the bankfull concept is appropriate for the two large Sixteen Mile Creek watercourses at Crossings 7 and 15, and thus these geometric bankfull channel measurements are the most consistent with respect to the terminology.

The geomorphic assessment results were used to make recommendations with respect to culvert and bridge designs, including bankfull width criteria for crossing spans, which were subsequently applied to the hydraulic modeling to iteratively arrive at the proposed culvert specifications (**Table 3**).

Table 2: Documentation of existing conditions for each watercourse at the Britannia Road crossings.

Crossing #	Vantage	Adjacent Landuse	Valley Setting Landform	Bed Material Type	Bank and Riparian Corridor Vegetation	Evidence of Existing Bank Erosion	Presence of Roadside Ditches	Inferred Flow Type	Channel Form
1	Upstream	Agricultural	Valley not well defined, gradual side-slopes	Vegetated (long grasses), fine material	Long grasses, herbaceous	Minor slumping of grass sod	Present, both sides of channel	Ephemeral, intermittent	Vegetated swale, partially defined channel
	Downstream								
2	Upstream	Agricultural	Valley not well defined, gradual side-slopes	Vegetated (long grasses, cattails), fine material	Long grasses, herbaceous	None	Present, both sides of channel	Ephemeral, intermittent	Vegetated swale, partially defined channel
	Downstream								
3	Upstream	Agricultural	Gradual slopes, no defined valley	Vegetated (turf, long grasses, cattails), fine material	Long grasses, herbaceous	None	Roadside ditch	Ephemeral, intermittent	Roadside ditch (vegetated)
	Downstream						Present, both sides		Vegetated swale
4	Upstream	Agricultural	Gradual slopes, no defined valley	Vegetated (long grasses), fine material	Long grasses, herbaceous, locally bare	Local bare soil	Present, both sides of channel	Ephemeral	Agricultural swale
	Downstream								
5	Upstream	Agricultural and naturalized-wooded	Valley not well defined, gradual side-slopes	Vegetated (turf, long grasses, cattails), fine material	Long grasses, herbaceous	None	Present, both sides of channel	Ephemeral, intermittent	Vegetated swale, partially defined channel
	Downstream								
5a	Upstream	Agricultural	Gradual slopes, no defined valley	Vegetated (short, long grasses), fine material	Long grasses, herbaceous, locally bare	None	Roadside ditch	Ephemeral	Agricultural swale (converted to ditch)
	Downstream						Present, both sides		
6	Upstream	Agricultural and naturalized-wooded	Valley not well defined, gradual side-slopes	Vegetated (turf, long grasses, cattails), fine material	Long grasses, herbaceous, local trees and shrubs	None	Present, both sides of channel	Ephemeral, intermittent	Vegetated swale, partially defined channel
	Downstream								
7 (Bridge)	Upstream	Naturalized-wooded	Defined valley incised ~20 m below uplands	Cobble, gravel	Long grasses, herbaceous, local trees and shrubs	Cutbanks	None	Perennial	Defined channel, meandering
	Downstream								
8	Upstream	Agricultural	Gradual slopes, no defined valley	Vegetated (short, long grasses), fine material	Short, long grasses, herbaceous, locally bare	None	Present, both sides of channel	Ephemeral	Agricultural swale
	Downstream								
9	Upstream	Pasture (cattle)	Gradual slopes, no defined valley	Vegetated (short, long grasses, cattails), fine material	Short, long grasses, locally bare, trees/shrubs	Bare banks (livestock access)	Present, both sides of channel	Ephemeral, intermittent	Vegetated swale, defined
	Downstream	Barn, laneway, residential lot							Online pond
10	Upstream	Cattle lot and barn	Gradual slopes, no defined valley	Vegetated (short, long grasses), fine material	Short, long grasses, herbaceous, locally bare	None	Roadside ditch	Ephemeral	Pond, ditch
	Downstream	Agricultural					Present		Agricultural swale
11	Upstream	Road embankment, residential	No defined valley	Vegetated (short, long grasses, cattails), fine material	Short, long grasses, herbaceous, local trees	None	Parallel to road	Ephemeral, intermittent	Roadside ditch
	Downstream	Agricultural (possibly fallow)	Valley incised ~5 m below uplands				Present		Vegetated swale, defined
12	Upstream	Agricultural	Gradual slopes, no defined valley	Vegetated (short, long grasses), fine material	Short, long grasses, herbaceous, locally bare	None	Present (locally bare)	Ephemeral	Agricultural swale
	Downstream								
13	Upstream	Orchard, manicured lawn	Gradual slopes, no defined valley	Fine material	Herbaceous, bare	None	Channel flows parallel to road	Ephemeral	Roadside ditch
	Downstream	Agricultural							
14	Upstream	Residential lots, lawns	No defined valley	Vegetated (short, long grasses, turf), fine material	Manicured grasses, locally bare	None, locally bare due to construction	Present, both sides of channel	Ephemeral, intermittent	Vegetated swale, partially defined channel
	Downstream	Agricultural	Valley not well defined, gradual side-slopes						
15 (Bridge)	Upstream	Naturalize-wooded	Defined valley incised ~15 m below uplands	Cobble, gravel	Long grasses, herbaceous, local trees and shrubs	Outflanked dam structure	Present	Perennial	Defined channel, meandering
	Downstream					Cutbanks			
16	Upstream	Agricultural	No defined valley	Vegetated (turf, long grasses), fine material	Long grasses, herbaceous	None, local rip-rap	Present, both sides of channel	Ephemeral	Roadside ditch
	Downstream	Residential lots, agricultural	Valley not well defined, gradual side-slopes						Vegetated swale
17	Upstream	Agricultural	Valley not well defined, gradual side-slopes	Vegetated (long grasses), fine material	Long grasses, herbaceous	None	Present, both sides of channel	Ephemeral, intermittent	Vegetated swale, partially defined channel
	Downstream								
18	Upstream	Naturalized-wooded, railway, hydro corridor	Valley partially defined by road embankments, gradual slopes	Vegetated (long grasses, cattails), fine material	Long grasses, herbaceous, locally bare, trees/shrubs	None, local rip-rap	Present	Ephemeral, intermittent	Vegetated swale, partially defined channel
	Downstream								

Table 3: Summary of average bankfull width and depths of watercourses at crossings of Britannia Road, with recommended culvert spans to meet 2 x bankfull width criteria

Crossing #	Existing				Drainage Area Models[2]			Proposed		
	Culvert Span (m)	Field Avg Width (m)	Field Max Width (m)	Field Avg. Depth (m)	Drainage Area (km^2)	Predicted Avg Width (m)	Upper 95% Prediction Interval	Bankfull Width (m)	2 x Bankfull Width (m)	Culvert Span (m)
1	2.45	2.4	3.3	0.6	1.68	2.3	3.1	2.4	4.8	6.00
2	1.5	3.7	6.0	0.4	1.44	2.1	2.9	3.7	7.4	7.40
3	5.25	1.1	1.4	0.2	0.7	1.6	2.0	1.6	3.2	3.20 [x2]
4	0.42 ø	1.4	2.2	0.3	0.17	0.9	1.0	1.4	-	4.40
5	2.48	3.8	5.4	0.4	1.64	2.3	3.0	3.8	7.6	7.60
5a	(0.4 ø)[1] → eliminated	1.5	1.5	0.4	0.17	0.9	1.0	1.5	-	2.00
6	(0.9 ø x2)[1] → 2.4 [x2]	4.9	9.2	0.6	2.22	2.6	3.5	4.9	9.8	10.20
7	19.8	11.4	12.3	0.7	128.7	13.6	27.0	13.6	27.2	30.00
8	0.5 ø	1.9	1.9	0.1	0.37	1.2	1.4	1.9	-	4.50
9	3.0	-	-	-	1.38	2.1	2.8	2.1	4.2	4.80 [x2]
10	0.5 ø	-	-	-	0.13	0.8	0.9	0.8	-	4.00
11	6.0	7.0	8.7	0.5	2.99	2.9	4.1	7.0	14.0	(6.00)[3]
11 new	-	-	-	-	-	-	-	7.0	14.0	14.40
12	0.8 ø	0.7	1.0	0.3	0.05	0.5	0.5	1.0	-	3.00
13	0.5 ø	-	-	-	0.07	0.6	0.6	0.6	-	2.00
14	1.85	3.6	4.5	0.3	1.07	1.9	2.5	3.6	7.2	7.20
15	24.4	16.0	20.4	0.9	142.5	14.3	28.4	16.0	32.0	32.00
16	1.2	0.9	1.0	0.3	0.4	1.3	1.5	1.3	2.6	2.60
17	0.9 ø	6.9	8.4	0.4	3.44	3.1	4.4	6.9	13.8	13.8
18	3.5 [x2]	9.2	13.5	0.9	1.36	2.1	2.8	~ 3	-	(3.5 [x2])[3]

Notes:
1. Two culverts were replaced during Britannia EA study with upgrades at Regional Road 25 intersection, including Crossing 5a (diverted to ditch drainage) and Crossing 6 (Concrete Box [x2]).
2. Drainage area (A_d) models for bankfull width (w) are based on Phillips and Desloges (2012) relation of $w = a A_d^b$, where for greater Toronto area a = 1.85 and b = 0.41 (average width prediction); and for all of southern Ontario a = (1.2+1.18) and b = 0.5 (upper 95% prediction interval of model statistics).
3. Expected that existing structures to be maintained at Crossings 11 and 18.

Legend
- Culverts – Regulated Watercourses
- Bridges – Regulated Watercourses
- Culverts – Unregulated drainage features, with culverts expected to be maintained for storm water
- Culverts – Unregulated drainage features, with temporary culverts

4.0 Stability Analysis

The stability analysis was conducted in order to demonstrate that hydraulic changes resulting from the proposed culverts along Britannia Road within the study area will not increase risks of channel instability. The two parameters used to assess erosion risks were channel velocity and boundary shear stress. More specifically, average cross-sectional velocities were used to assess the local boundary stability in the channel *at* each crossing (i.e., risk of local scour); whereas average boundary shear stress was used to assess reach-scale channel stability *in the vicinity* of the crossing (i.e., risk of channel degradation).

Permissible values of velocity and shear stress are recommended based on classifications of vegetation or sediment boundary types referenced to the categories presented by Fischenich (2001). For the stability analysis, final results of the hydraulic analysis are evaluated to compare existing and proposed values of velocity and shear stress, as well as to compare proposed conditions with the permissible recommendations. In order to not increase channel instability, the aim was to confirm that:

1) The proposed channel velocity and shear stress at each crossing will be maintained or decreased relative to existing conditions; and
2) The frequency of permissible exceedances under proposed conditions at each crossing will be the same or less frequent compared to existing conditions.

Translation of the final hydraulic analysis results into the stability analysis varied between crossings depending on the hydraulic modeling application used:

- **HY-8 Models** (Crossings 1, 2, 3, 4, 5, 5a, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18)
  - Velocities (m/s) are based on Culvert Outlet Velocity from the HY-8 output table
  - Shear Stress (Nm^{-2}) is based on equation $\tau_o = \rho_w \cdot g \cdot d \cdot s$ where ρ_w is the density of water ($\rho_w \approx 1000$ kg/m^2); g is the acceleration due to gravity ($g = 9.806$ ms^{-2}); d is the average flow depth (m); and s is the channel slope (assumed to be approximately equivalent to the water surface energy gradient over reach scales).
    - Average flow depth (d) is based on the average of three depth values taken from the HY-8 output tables: upstream, culvert, and downstream depths.
    - Average channel slope (s) is based on reach-scale longitudinal profiles from the provincial digital elevation model (DEM), with review of local grades from detailed field survey measurements prepared by Delcan Corporation.
- **HEC-RAS Models** (Crossings 7, 11, and 5)
  - Velocities (m/s) are based on the Channel Velocity from the cross-section immediately downstream of the culvert in the HEC-RAS output tables
  - Shear stress (Nm^{-2}) is based on the Channel Shear averaged over multiple cross-sections within an interpreted zone of influence (cross-sections where hydraulics are effectively modified by the proposed culvert relative to existing), analogous to reach-scale interpretations.

Flood frequencies from the hydraulic analysis which were used in the stability analysis included the 2, 5, 10, 20, 50, and 100 year floods; however, the 2 year flood was not contained in the HEC-RAS models for Crossings 7 and 15. Results for the Regional flood hydraulics were not considered in the stability analysis, as widespread instability would be expected in most watercourses under both existing and proposed conditions. The summary results of the stability analysis are presented for each crossing in **Table 4**, where a range of velocities and shear stresses are reported based on the modeled range of flood frequencies (i.e., 2 or 5 to 100 year). Detailed results comparing existing, proposed, and permissible values for each flood frequency at each crossing are provided in **Appendix B**. Details on the origin of the discharge values for the flood frequencies are documented in the Hydraulic Analyses of Stream Crossings and Storm Water Management Alternatives Assessment Report.

Overall final results of the stability analysis demonstrate proposed velocity and shear stress decreases compared to existing conditions at all crossings, for nearly all flood frequencies. This finding was expected based on increased culvert spans and capacities, and the final results were arrived at iteratively by adjusting the models to meet hydraulic and ecological criteria, with additional iterations in a few cases to meet stability objectives. The only increases remaining in the final hydraulic modeling (for EA Study) are:

- Minor increases in shear stress at Crossing 4 (HY-8) under 20 and 50 year flood conditions, but with proposed values still below permissible recommendations.
- Minor velocity increases at Crossing 11 (HEC-RAS), but with proposed values still well below permissible recommendations. These increases are interpreted to be due to local reductions in the floodline elevations downstream of Britannia which slightly increase water surface energy gradients through the reach.
- Minor increases in velocity at Crossing 12 (HY-8) under 10, 20, and 50 year flood conditions, with proposed values still below permissible recommendations.

In all of the above cases the increases are considered to be very minor with respect to model accuracy and permissible thresholds. In particular for the HY-8 models (Crossings 4 and 12) such minor differences in flow velocity and depth are sensitive to variations in model assumptions regarding flow types and governing hydraulic conditions through the culvert at each flood frequency. While some local variability in the cross-sectional shear stress and velocity results are indicated in the HEC-RAS model outputs (Crossings 7, 11, and 15), no other relevant increases (except for velocities at Crossing 11) have been interpreted based on the analysis framework outlined above.

Permissible exceedances for existing conditions were noted at most crossings (**Table 4**). For velocity, 13 of 19 of the existing crossing structures show exceedance frequencies of less than every 2 – 5 years, while for shear stress only two crossings show similar exceedance frequencies. In all cases, the frequency of permissible exceedances has been decreased for proposed conditions (i.e., the return period for exceedance events increases). Frequent exceedances for both existing and proposed conditions are indicated for the Main and East Branches of Sixteen Mile Creek (Crossings 7 and 15) under existing and proposed conditions, which is expected to maintain natural sediment transport processes (with only minor decreases in exceedance frequency associated with widening the bridge spans at both crossings).

Table 4: Summary of Stability Analysis results for Britannia road crossings based on flood frequency exceedances of recommended permissible velocity and shear stress. Detailed results are presented in **Appendix B** (Note: Analysis for Crossing 5a has not been provided).

#	Model	Permis[1] Velocity (m/s)	Existing[2] Velocities (m/s)	Exceed Freq.[3]	Proposed[2] Velocities (m/s)	Exceed Freq.[3]	Permis[1] Shear (Nm^{-2})	Existing[2] Shear Stress (Nm^{-2})	Exceed Freq.[3]	Proposed[2] Shear Stress (Nm^{-2})	Exceed Freq.[3]
1	HY-8	1.2 - 1.8	0.9 - 4.7	> 5 yr	0.4 - 2.2	> 20 yr	57 - 81	17 - 25	-	15 - 20	-
2	HY-8	1.2 - 1.8	2.4 - 3.0	< 2 yr	0.6 - 1.3	> 50 yr	57 - 81	25 - 37	-	13 - 25	-
3	HY-8	1.1 - 1.8	0.2 - 0.7	-	0.2 - 0.5	-	45 - 81	31 - 48	> 50 yr	21 - 36	-
4	HY-8	1.2 - 1.8	1.8 - 1.9	< 2 yr	0.2 - 1.4	<100 yr	57 - 81	25 - 32	-	19 - 34	-
5	HY-8	1.1 - 1.8	1.2 - 1.9	< 2 yr	0.4 - 0.6	-	45 - 81	10 - 21	-	8 - 17	-
6	HY-8	1.1 - 1.8	1.7 - 2.6	< 2 yr	0.2 - 0.5	-	45 - 81	17 - 33	-	12 - 21	-
7	HEC-RAS	0.8 - 2.3	1.3 - 2.3	<< 5yr	0.9 - 1.5	< 5 yr	16 - 96	44 - 62	<< 5 yr	38 - 53	<< 5 yr
8	HY-8	0.9 - 1.2	2.1 - 2.1	< 2 yr	0.4 - 1.1	< 50 yr	34 - 45	55 - 63	< 2 yr	13 - 28	-
9	HY-8	0.9 - 1.2	1.1 - 1.9	< 2 yr	0.3 - 0.6	-	34 - 45	15 - 44	< 50 yr	12 - 35	~100 yr
10	HY-8	0.9 - 1.2	2.0 - 2.5	< 2 yr	0.2 - 0.5	-	34 - 45	6 - 12	-	3 - 5	-
11	HEC-RAS	1.1 - 1.8	0.4 - 1.1	~100 yr	0.5 - 1.1	~100 yr	45 - 81	7 - 15	-	6 - 13	-
12	HY-8	0.9 - 1.2	0.3 - 0.9	>100 yr	0.3 - 0.7	-	34 - 45	15 - 35	~100 yr	7 - 11	-
13	HY-8	0.5 - 0.7	1.0 - 1.4	< 2 yr	0.2 - 0.5	>100 yr	~ 18	6 - 12	-	3 - 5	-
14	HY-8	1.1 - 1.8	1.8 - 2.7	< 2 yr	0.5 - 1.2	~ 50 yr	45 - 81	12 - 26	-	9 - 16	-
15	HEC-RAS	0.8 - 2.3	1.1 - 1.8	<< 5 yr	1.0 - 1.5	< 5 yr	16 - 96	13 - 18	< 20 yr	12 - 16	< 50 yr
16	HY-8	1.2 - 2.1	1.3 - 2.0	< 2 yr	0.4 - 0.8	-	~ 101	8 - 14	-	6 - 11	-
17	HY-8	1.2 - 1.8	2.8 - 3.0	< 2 yr	0.5 - 1.0	-	57 - 81	9 - 12	-	5 - 9	-
18	HY-8	1.2 - 1.8	0.2 - 0.4	-	0.2 - 0.4	-	57 - 81	5 - 7	-	5 - 7	-

Notes:

1. Permissible Velocity and shear stress are based on values reported for vegetation and bed material types by Fischenich (2001), and as documented in **Table 3** of this report.
2. Existing and proposed velocities and shear stress results are reported as ranges from hydraulic modeling of 2 or 5 – 100 year flood frequencies.
3. Exceedance Frequency is based on the flood frequency which exceeds the minimum permissible recommendation. No value indicates there were no results which exceeded permissible recommendations.

Legend

- Culverts (HY-8 Models) – Regulated
- Bridges / Culverts (HEC-RAS Models) - Regulated
- Culverts (HY-8 Models) – Unregulated to be maintained for storm water
- Culverts (HY-8 Models) – Unregulated temporary culverts

5.0 Culvert Alignment Recommendations

A planning framework was suggested for culvert alignment recommendations at the Britannia Road EA stage to allow for consideration of alignment impacts to the natural environment and to road construction in advance of detailed design. In many cases, either significant channel realignments will be required in order to match perpendicular culverts across the roadway axis, or oblique culvert alignments will be required to minimize channel realignments. Construction issues were also considered as any opportunities to install new culverts outside the existing culvert footprint can allow for construction in the dry which decreases costs and risks to the aquatic environment (i.e., can help to minimize requirements for by-pass channels, dam-and-pump procedures, and other risks associated with wet weather storm contingencies). To investigate a preferred culvert alignment at each crossing, a number of conceptual alternatives were drafted at each crossing (**Appendix C**).

- **Option 1** – culvert **perpendicular** to the roadway axis; **west** of the existing culvert footprint to facilitate construction where possible; and **minimizing** channel realignment on one side of the road where possible.
- **Option 2** – culvert **perpendicular** to the roadway axis; more or less **centred** on the existing culvert footprint; and **balancing** channel realignments on both sides of the road where possible.
- **Option 3** – culvert **perpendicular** to the roadway axis; **east** of the existing culvert footprint to facilitate construction where possible; and **minimizing** channel realignment on one side of the road where possible.
- **Option 4** – culvert **oblique** to the roadway axis; and **minimizing** channel realignment on both sides of the road where possible.

Within the Boyne Survey Area for future development, a strong preference for culvert alignments perpendicular to the road (i.e., 90^o) was indicated by Conservation Halton (see **Appendix D**) to minimize the culvert lengths and consequent impacts to aquatic habitat, in terms of enclosure lengths and fish passage concerns in particular. It was also suggested by Conservation Halton that perpendicular culverts have been assumed in development plans; however it is considered in this analysis that minimal offsets of the channel on the north side due to oblique culvert alignments could easily be accommodated within the development restoration designs of relatively wide stream corridors. In some cases, the potential offsets and/or channel realignments could be greater for perpendicular compared to oblique alignments relative to the locations of the existing culvert (i.e., Crossing 3). Further, culvert alignment recommendations assume that road construction will precede development and that channel realignments on the north side of the road will be undertaken by Halton Region (in addition to the south side where necessary).

The conceptual alternative options are reviewed below for each watercourse crossing of Britannia Road to arrive at a recommended culvert alignment. For select crossings where graphical representation of the options was most relevant, schematic maps are presented in **Appendix C**. In a few cases, the recommended option does not conform with Conservation Halton's preference for strictly perpendicular culverts adjacent to the Boyne Survey Area. For these cases, a preferred alternative to satisfy Conservation Halton is also proposed and identified in **Appendix C**. Further consultation will be required at the detailed design stage to resolve disparities between the recommended and CH alignments.

Crossing 1 – The recommended culvert alignment is illustrated in **Appendix C** as a hybrid of **Options 3 and 4**. The recommended alternative aims to minimize channel realignments on both sides of the roadway, while also being located beyond the existing culvert footprint to facilitate construction. The oblique culvert angle is only expected to increase the culvert length by about 2 m.

Option 2 is proposed as the preferred alternative to satisfy Conservation Halton (CH) (**Appendix C**), which is perpendicular to the roadway axis and would minimize channel realignment on the south side. For Option 2, substantial channel realignment will be required by Halton Region on the north side of the road assuming that the road precedes development. Another option which could be explored at detailed design is to offset the culvert further east to minimize channel realignment on the north side, however, this would then require more substantial channel realignment on the south side.

Crossing 2 – The recommended culvert alignment is illustrated in **Appendix C** as a hybrid of **Options 3 and 4**. The recommended alternative aims to minimize channel realignments on both sides of the roadway, while also being located beyond the existing culvert footprint to facilitate construction. The oblique culvert angle is only expected to increase the culvert length by about 1 m.

Option 3 is proposed as the preferred alternative to satisfy Conservation Halton (CH) (**Appendix C**), which is perpendicular to the roadway axis and would minimize channel realignment on the south side. For Option 3, substantial channel realignment will be required by Halton Region on the north side of the road assuming that the road precedes development. Another option which could be explored at detailed design is Option 1, however, this would then require more substantial channel realignment on the south side.

Crossing 3 – The recommended culvert alignment is illustrated in **Appendix C** as a hybrid of **Options 1 and 4**. The recommended alternative aims to minimize channel realignment the south side of the roadway, to balance channel realignment on the north side with consideration of culvert length, while also being located beyond the existing culvert footprint to facilitate construction. The oblique culvert angle is only expected to increase the culvert length by about 2 m.

Option 1 is proposed as the preferred alternative to satisfy Conservation Halton (CH) (**Appendix C**), which is perpendicular to the roadway axis and would minimize channel realignment on the south side. For Option 1, substantial channel realignment will be required by Halton Region on the north side of the road assuming that the road precedes development. Another option which could be explored at detailed design is Option 3, however, this would then require more substantial channel realignment on the south side.

Crossing 4 – The recommended culvert alignment is illustrated in **Appendix C** as a hybrid of **Options 3 and 4**. The recommended alternative aims to minimize channel realignments on both sides of the roadway, while also being located beyond the existing culvert footprint to facilitate construction. The oblique culvert angle is only expected to increase the culvert length by about 2 m.

Option 3 is proposed as the preferred alternative to satisfy Conservation Halton (CH) (**Appendix C**), which is perpendicular to the roadway axis and would minimize channel realignment on the south side. For Option 3, substantial channel realignment will be required by Halton Region on the north side of the road assuming that the road precedes development. Other perpendicular options could also be explored at detailed design, however, all would require balancing some amount of channel realignment on either side of the road. Although this drainage feature is unregulated and the crossing has been identified as a temporary culvert, it is expected that the culvert will be maintained for a future storm management outlet. Thus, minimal channel realignment on the south side of the road is recommended.

Crossing 5 – The recommended culvert alignment is illustrated in **Appendix C** as **Option 3**. The recommended alternative is appropriate for the stream corridor alignment (although local low-flow channel realignments would be required on both sides of the road), while also being located beyond the existing culvert footprint to facilitate construction. The recommended culvert alignment is perpendicular to the roadway, so it is expected to meet Conservation Halton's preference.

Crossing 5a – As this culvert was recently removed in 2012 (associated with intersection upgrades at Regional Road 25), no recommendation for a proposed culvert alignment is provided. However, the current drainage alignments in roadside ditches will need to be considered during detailed design and upstream flows may still need to be accommodated temporarily in advance of development.

Crossing 6 – Crossing 6 – The culvert at Crossing 6 was recently replaced in 2012 (associated with intersection upgrades at Regional Road 25). While it is recommended that the culvert be replaced to meet hydraulic criteria under the EA Study, it has been assumed in this analysis that the existing perpendicular culvert alignment will be extended. Should culvert replacement be considered during detailed design to meet the hydraulic and ecological criteria outlined in the Britannia EA study (and with further consultation with regulatory agencies), then other culvert alignment options may be explored.

Crossing 7 – Bridge

Crossing 8 – The recommended culvert alignment is illustrated in **Appendix C** as **Option 3**. The recommended alternative minimizes channel realignments on both sides of the road, while also being located beyond the existing culvert footprint to facilitate construction. The recommended culvert alignment is perpendicular to the roadway, so it is expected to meet Conservation Halton's preference. Although this drainage feature is unregulated and the crossing has been identified as a temporary culvert, it is expected that the culvert will be maintained for a future storm management outlet.

Crossing 9 – The recommended culvert alignment is illustrated in **Appendix C** as a hybrid of **Options 1 and 4**. The recommended alternative aims to balance channel realignment on the north side with consideration of culvert length, while also being located beyond the existing culvert footprint to facilitate construction. Removal of a private online pond on the south side will be required, and the recommended culvert alignment provides an appropriate transition to the downstream channel. The oblique culvert angle is only expected to increase the culvert length by about 3 m.

Option 1 is proposed as the preferred alternative to satisfy Conservation Halton (CH) (**Appendix C**), which is perpendicular to the roadway axis. For Option 1, more channel realignment will be required by Halton Region on the north side of the road assuming that the road precedes development. With removal of the online pond on the south side, the Option 1 culvert alignment will require a sharper bend in the restored channel downstream, and thus greater mitigation of erosion risks within the private property. Another option which could be explored at detailed design is to offset the culvert further west to alleviate the channel bend on the south side, however, this would then require more substantial channel realignment on the north side.

Crossing 10 – The culvert alignment at this crossing is recommended to be determined at detailed design. As a temporary culvert, it is expected that this drainage feature will be eliminated by development. As such a number temporary drainage options are appropriate for consideration, including:

- Extending the existing culvert across the new roadway, and re-instating a temporary drainage channel along the south side of the road to connect with the existing swale downstream (modeled option in hydraulic analysis).
- Installing a new temporary culvert where the new roadway crosses the existing swale (perpendicular culvert with channel realignment and oblique culvert without channel realignment options may be considered).
- Diverting temporary flows along the north side of the new roadway into the proposed storm sewer drainage system for Britannia road (possibly outleting to watercourse at Crossing 11).

Crossing 11 – The recommended culvert alignment is illustrated in **Appendix C** as a hybrid of **Options 2 and 4**. The recommended alternative aims to balance channel realignments on both sides of the roadway with the proposed culvert length, however, some realignment of the valley corridor will also be required (i.e., watercourse is about 5 m below the surrounding uplands). The oblique culvert angle is expected to increase the culvert length by about 13 m, however more perpendicular options will require even more extensive earth works to reconstruct the valley.

A solution between **Option 2 and 3** is proposed as the preferred alternative to satisfy Conservation Halton (CH) (**Appendix C**), which is perpendicular to the roadway axis. All options should be further explored at detailed design (in consultation with Conservation Halton) to minimize the amount of channel realignment and earth works required to realign the valley corridor upstream and downstream of the new roadway. A detailed topographic survey will be required in this area.

Crossing 12 – The recommended culvert alignment is illustrated in **Appendix C** as **Option 4**. The recommended alternative aims to avoid channel realignments, and the oblique angle required should only increase the culvert length by about 1 – 2 m. While the recommended culvert alignment does not meet Conservation Halton's preference for perpendicular culverts, this drainage features is unregulated and it is expected that the culvert will be temporary pending development on the north side of the road. Other options for Halton Region to temporarily divert flows west to Crossing 11 by surface drainage channels or the proposed storm sewer system may also be explored at detailed design (in consultation with Conservation Halton).

Crossing 13 – The recommended culvert alignment is perpendicular to the road way and centred on the existing culvert (Option 2). This drainage features is unregulated and the existing culvert largely transmits flows from roadside ditches, however the dominant drainage direction (north or south) may vary depending local conditions in the adjacent fields each year. Further investigation during detailed design is recommended to ensure positive drainage of properties on both sides of the roadway, and other options for diverting flows or integrating the drainage into the proposed storm sewer system may be considered.

Crossing 14 – The recommended culvert alignment is illustrated in **Appendix C** as a hybrid of **Options 2 and 4**. The recommended alternative aims to avoid channel realignment on the north side within private residential properties, while minimizing channel realignment on the south side. This alternative will require fairly substantial channel realignment on the south side of the road by Halton Region. The oblique culvert angle is only expected to increase the culvert length by about 1 m. While the recommended culvert alignment does not strictly meet Conservation Halton's preference for perpendicular culverts, and the watercourse is regulated, it is outside the Boyne Survey Area where perpendicular culverts have been specifically requested.

Crossing 15 – Bridge

Crossing 16 – The recommended culvert alignment is illustrated in **Appendix C** as **Option 2**. The recommended alternative aims to avoid channel realignment on the south side within private residential properties. Existing ditch drainage on the north side may need to be replicated locally in drainage channels on the north side of the new roadway to maintain connection with upstream flows from the northwest. The recommended culvert alignment is perpendicular to the roadway (as per CH comments).

Crossing 17 – The recommended culvert alignment is illustrated in **Appendix C** as a hybrid of **Options 1 and 4**. The recommended alternative aims to minimize channel realignment on the south side of the roadway, to balance channel realignment on the north side with consideration of culvert length, while also being located beyond the existing culvert footprint to facilitate construction. The oblique culvert angle is only expected to increase the culvert length by about 1 m. While the recommended culvert alignment does not strictly meet Conservation Halton's preference for perpendicular culverts, and the watercourse is regulated, it is outside the Boyne Survey Area where perpendicular culverts have been specifically requested. For other strictly perpendicular culvert options (e.g, Options, 1, 2, and 3), more channel realignment would be required by Halton Region on the north and south sides of the road.

Crossing 18 – As it has been assumed that the existing culvert will be maintained, no culvert alignment recommendations are provided for this crossing.

6.0 Conclusions and Recommendations

The overall objective for the environmental assessment along Britannia Road is to document existing conditions and to form the basis for assessing design alternatives. The fluvial geomorphology report provides a geomorphic assessment of watercourses in terms of existing forms and functions and the potential impacts of road crossings within the study area. In order to document the existing conditions at each crossing and assess the influences of proposed road widening on channel processes, a number of approaches were applied. These included field assessments and basic stability analyses to demonstrate that hydraulic changes resulting from the proposed culverts will not increase risks of channel instability. In addition, a planning framework was developed to make culvert alignment recommendations for the proposed culverts based on consideration of culvert length, channel realignments, and construction issues. The geomorphic assessment results were used to make recommendations with respect to culvert and bridge designs, including bankfull width criteria for crossing spans, which were subsequently applied to the hydraulic modeling to iteratively arrive at the proposed culvert specifications.

Existing conditions

- Most (17 of 19) crossings are considered to be ephemeral vegetation-dominated swales (or ditches) typically draining less than 2-3 km^2, with no native sources of coarse bed load material.
- Two crossings (Crossings 7 and 15) are larger coarse-grained alluvial channels (i.e., shear-dominated, draining 125-150 km^2) situated within well defined valley landforms incised 15-20 m below the surrounding uplands.

Hydraulic Analysis and Bankfull Widths

- The existing culverts at most crossings were confirmed to be undersized in terms of both hydraulic and ecological criteria.
- Bankfull recommendations were made based on field evidence and drainage area models for culvert span specifications used in final hydraulic modeling (for the EA). In terms of geomorphic input, the bankfull concept is most appropriate for large channels (i.e., Crossings 7 and 15), but has also been generally applied to the small vegetation-dominated drainage features to help constrain expected morphological limits of channel width (**Appendix D**). Complete maintenance of natural processes in culverts on vegetation-dominated channels is unrealistic, but sufficient culvert spans should be provided at all crossings in order to minimize local interruptions in geomorphic processes and mitigate reach scale impacts of the crossings.
- Recommendations for culvert spans have been provided as 2 times the bankfull width to satisfy Conservation Halton's ecological objectives (as per references to the draft Conceptual Fisheries Compensation Plan (CFCP) for the Boyne Survey, see comments **Appendix D**). The 2 times bankfull criteria is considered sufficient for the small ephemeral watercourses, and is considered appropriate for the large perennial watercourses (as a minimum) from a geomorphic perspective.

Stability Analysis

- The aim of the stability assessment was to demonstrate relative decreases in both the existing velocities and shear stresses compared to proposed conditions, as well as to minimize absolute exceedances of permissible values (as per Fischenich, 2001). Average cross-sectional velocities were used to assess the local boundary stability in the channel at each crossing, whereas, average boundary shear stress was used to assess reach-scale channel stability in the vicinity of the crossing.
- Overall, the final results of the stability analysis demonstrate proposed velocity and shear stress decreases compared to existing conditions at all crossings, for nearly all flood frequencies. This finding was expected based on increased culvert spans and capacities, and the final results were arrived at iteratively by adjusting the models to meet hydraulic and ecological criteria, with additional iterations in a few cases to meet stability objectives.
- Permissible exceedances of velocity and/or shear stress were noted at some crossings for both existing conditions; however, in all cases the frequency of permissible exceedances has been decreased for proposed conditions (i.e., the return period for exceedance events increases).
- For the Main and East Branches of Sixteen Mile Creek (Crossings 7 and 15), recommendations for increased spans at both bridge crossings will not only alleviate flood levels, but will also relieve existing constraints on the channel in terms of geomorphic processes. Natural sediment bedload transport processes are expected to be maintained relative to existing conditions.

Culvert Alignment Recommendations

- Recommended culvert alignments are provided within a conceptual planning framework based on an analysis of four primary culvert alignments which were drafted as three options for channel realignment required for perpendicular culverts, as well as one option of a longer culvert length oblique to the road which would minimize channel realignments (Section 5.0 and **Appendix C**). Construction issues are also considered in the analysis.
- Within the Boyne Survey Area, a strong preference for culvert alignments perpendicular to the road (i.e., 90^o) was indicated by Conservation Halton to minimize the culvert lengths and consequent impacts to aquatic habitat, in terms of enclosure lengths and fish passage concerns in particular.
- In a few cases, the recommended culvert alignment options do not conform with Conservation Halton's preference for strictly perpendicular culverts adjacent to the Boyne Survey Area. For these cases, a preferred alternative to satisfy Conservation Halton is also proposed (Section 5.0 and **Appendix C**). Further consultation will be required at the detailed design stage to resolve disparities between the recommended and CH alignments.
- Required channel realignments based on recommended culvert alignments are outlined in Section 5.0 and **Appendix C**.

Recommendations

- Enlarged culvert spans have been recommended at all undersized crossings to meet hydraulic and ecological criteria, and these recommendations are also considered appropriate from a geomorphic perspective.
- For culverts, use of open bottom structures is recommended (as per the draft Conceptual Fisheries Compensation Plan (CFCP) for the Boyne Survey). The CFCP study also recommends the use of natural substrates.

- Natural (round stone) substrates through open bottom culverts are recommended, however the small ephemeral watercourses typically have no native sources of coarse gravel and cobble to replace within the open bottom culverts and therefore some mixture of imported natural round stone and native fine material would be required to maintain stable bed materials. The stone sizing should be specified at detailed design based on detailed hydraulic and geomorphic analyses (and further consultation with Conservation Halton).
- For channel realignments and culvert substrates, reference to Natural Channel Design approaches is recommended, but methods should be compatible with expected geomorphic form and function of ephemeral vegetation-dominated channels. In most cases, riffle-pool morphology using imported cobble/gravel may not be appropriate (with the exception of coarse substrate within the culverts themselves to satisfy engineering requirements).
- For the Main and East Branches of Sixteen Mile Creek (Crossings 7 and 15), no channel bed works are expected (i.e., no channel realignments), however, channel banks will need to be reconstructed locally associated with removal of the old abutments and installation of the new bridge structures. Local bank works and enhancements may also be considered where channel banks are impacted by construction or where existing bank erosion may be mitigated in the immediate vicinity of the proposed structures (in consultation with Conservation Halton).

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Appendix A

Photo Inventory

Crossing 1 – Looking upstream

Crossing 1 – Upstream facing culvert

Crossing 1 – Looking downstream

Crossing 1 – Downstream facing culvert

Crossing 2 – Looking upstream

Crossing 2 – Upstream facing culvert

Crossing 2 – Looking downstream

Crossing 2 – Downstream facing culvert

Crossing 3 – Looking upstream to the east

Crossing 3 – Upstream facing culvert

Crossing 3 – Looking downstream

Crossing 3 – Downstream facing culvert

Crossing 4 – Looking upstream

Crossing 4 – Upstream facing culvert

Crossing 4 – Looking downstream

Crossing 4 – Downstream facing culvert

Crossing 5 – Looking upstream

Crossing 5 – Upstream facing culvert

Crossing 5 – Looking downstream

Crossing 5 – Downstream facing culvert

Crossing 5a – Looking upstream

Crossing 5a – Upstream facing culvert

Crossing 5a – Looking downstream

Crossing 5a – Looking downstream

Crossing 6 – Looking upstream

Crossing 6 – Upstream facing culvert

Crossing 5a – Looking downstream

Crossing 5a – Downstream facing culvert

Crossing 7 – Looking upstream

Crossing 7 – Looking downstream

Crossing 8 – Looking upstream

Crossing 8 – Upstream facing culvert

Crossing 8 – Looking downstream

Crossing 8 – Downstream facing culvert

Crossing 9 – Looking upstream

Crossing 9 – Upstream facing culvert

Crossing 9 – Looking downstream

Crossing 9 – Looking downstream

Crossing 10 – Looking upstream

Crossing 10 – Upstream facing culvert

Crossing 10 – Looking downstream

Crossing 10 – Downstream facing culvert

Crossing 11 – Looking upstream

Crossing 11 – Upstream facing culvert

Crossing 11 – Looking downstream

Crossing 11 – Downstream facing culvert

Crossing 12 – Looking upstream to east

Crossing 12 – Looking west

Crossing 12 – Looking downstream

Crossing 12 – Downstream facing culvert

Crossing 13 – Looking upstream

Crossing 13 – Upstream facing culvert

Crossing 13 – Looking downstream

Crossing 13 – Downstream facing culvert

Crossing 14 – Looking upstream

Crossing 14 – Upstream facing culvert

Crossing 14 – Looking downstream

Crossing 14 – Downstream facing culvert

Crossing 15 – Looking upstream

Crossing 15 – Upstream facing bridge

Crossing 15 – Looking downstream

Crossing 15 – Downstream facing bridge

Crossing 16 – Looking upstream

Crossing 16 – Upstream facing culvert

Crossing 16 – Looking downstream

Crossing 16 – Downstream facing culvert

Crossing 17 – Looking upstream

Crossing 17 – Upstream facing culvert

Crossing 17 – Looking downstream

Crossing 17 – Downstream facing culvert

Crossing 18 – Looking upstream

Crossing 18 – Upstream facing culvert

Crossing 18 – Looking downstream

Crossing 18 – Downstream facing culvert

Updated Photos for Crossing 6, taken January 20, 2013
(upper left) - looking upstream
(lower left) - looking downstream
(lower right) - looking at upstream culvert face

Appendix B

Stability Analysis Results

Comparing Existing, Proposed, and Permissible Values of Velocity and Shear Stress

Crossing 1 (HY-8)

Flood	Discharge	Velocity (m/s)						Shear Stress (Nm^{-2})					
Frequency	(m^3s^{-1})	Permis.	Existing	Exceed	Proposed	Exceed	Diff.	Permis.	Existing	Exceed	Proposed	Exceed	Diff
2 yr	1.62	1.2	0.9	-	0.4	-	**-0.54**	57	17.0	-	14.6	-	**-2.5**
5 yr	2.62	1.2	1.2	Yes	0.5	-	**-0.70**	57	20.7	-	17.4	-	**-3.3**
10 yr	3.37	1.2	1.4	Yes	0.6	-	**-0.80**	57	22.8	-	19.5	-	**-3.3**
20 yr	4.14	1.2	2.3	Yes	1.1	Yes	**-1.20**	57	24.0	-	19.6	-	**-4.4**
50 yr	5.21	1.2	3.8	Yes	2.1	Yes	**-1.71**	57	24.5	-	18.5	-	**-6.0**
100 yr	6.08	1.2	4.7	Yes	2.2	Yes	**-2.50**	57	25.5	-	19.9	-	**-5.6**

Crossing 2 (HY-8)

Flood	Discharge	Velocity (m/s)						Shear Stress (Nm^{-2})					
Frequency	(m^3s^{-1})	Permis.	Existing	Exceed	Proposed	Exceed	Diff.	Permis.	Existing	Exceed	Proposed	Exceed	Diff
2 yr	1.48	1.2	2.4	Yes	0.6	-	**-1.8**	57	24.7	-	13.2	-	**-11.5**
5 yr	2.39	1.2	2.6	Yes	0.8	-	**-1.9**	57	28.9	-	16.2	-	**-12.7**
10 yr	3.06	1.2	2.8	Yes	0.9	-	**-1.9**	57	31.5	-	18.2	-	**-13.3**
20 yr	3.74	1.2	2.9	Yes	1.0	-	**-1.9**	57	33.6	-	21.2	-	**-12.5**
50 yr	4.68	1.2	2.9	Yes	1.2	Yes	**-1.8**	57	35.7	-	23.4	-	**-12.3**
100 yr	5.42	1.2	3.0	Yes	1.3	Yes	**-1.7**	57	37.1	-	24.9	-	**-12.1**

Crossing 3 (HY-8)

Flood	Discharge	Velocity (m/s)						Shear Stress (Nm^{-2})					
Frequency	(m^3s^{-1})	Permis.	Existing	Exceed	Proposed	Exceed	Diff.	Permis.	Existing	Exceed	Proposed	Exceed	Diff
2 yr	0.72	1.1	0.2	-	0.2	-	**0.0**	45	30.5	-	20.8	-	**-9.8**
5 yr	1.16	1.1	0.3	-	0.3	-	**0.0**	45	34.9	-	25.0	-	**-9.9**
10 yr	1.49	1.1	0.3	-	0.3	-	**0.0**	45	38.7	-	28.1	-	**-10.5**
20 yr	1.82	1.1	0.5	-	0.4	-	**-0.1**	45	41.2	-	31.3	-	**-9.9**
50 yr	2.28	1.1	0.5	-	0.4	-	**-0.1**	45	44.3	Yes	34.4	-	**-9.8**
100 yr	2.64	1.1	0.7	-	0.5	-	**-0.2**	45	47.9	Yes	36.4	-	**-11.5**

Comparing Existing, Proposed, and Permissible Values of Velocity and Shear Stress

Crossing 4 (HY-8)

Flood Frequency	Discharge (m^3s^{-1})	Velocity (m/s)						Shear Stress (Nm^{-2})					
		Permis.	Existing	Exceed	Proposed	Exceed	Diff.	Permis.	Existing	Exceed	Proposed	Exceed	Diff
2	0.61	1.2	1.9	Yes	0.2	-	**-1.6**	57	25.0	-	19.3	-	**-5.8**
5	1.00	1.2	1.9	Yes	0.3	-	**-1.6**	57	26.3	-	23.6	-	**-2.7**
10	1.34	1.2	1.9	Yes	0.4	-	**-1.5**	57	27.7	-	26.9	-	**-0.8**
20	1.74	1.2	1.9	Yes	0.5	-	**-1.4**	57	28.4	-	29.9	-	**1.5**
50	2.38	1.2	1.8	Yes	0.6	-	**-1.2**	57	30.4	-	34.5	-	**4.1**
100	2.97	1.2	1.8	Yes	1.4	Yes	**-0.4**	57	31.9	-	31.5	-	**-0.4**

Crossing 5 (HY-8)

Flood Frequency	Discharge (m^3s^{-1})	Velocity (m/s)						Shear Stress (Nm^{-2})					
		Permis.	Existing	Exceed	Proposed	Exceed	Diff.	Permis.	Existing	Exceed	Proposed	Exceed	Diff
2 yr	0.55	1.1	1.2	Yes	0.4	-	**-0.8**	45	9.6	-	7.5	-	**-2.1**
5 yr	0.86	1.1	1.4	Yes	0.4	-	**-0.9**	45	11.8	-	9.1	-	**-2.7**
10 yr	1.09	1.1	1.5	Yes	0.5	-	**-1.0**	45	14.2	-	11.3	-	**-2.9**
20 yr	1.33	1.1	1.7	Yes	0.5	-	**-1.2**	45	16.6	-	12.9	-	**-3.8**
50 yr	1.68	1.1	1.8	Yes	0.6	-	**-1.2**	45	19.0	-	15.3	-	**-3.8**
100 yr	1.97	1.1	1.9	Yes	0.6	-	**-1.3**	45	20.8	-	16.6	-	**-4.2**

Crossing 6 (HY-8)

Flood Frequency	Discharge (m^3s^{-1})	Velocity (m/s)						Shear Stress (Nm^{-2})					
		Permis.	Existing	Exceed	Proposed	Exceed	Diff.	Permis.	Existing	Exceed	Proposed	Exceed	Diff
2 yr	0.85	1.1	1.7	Yes	0.2	-	**-1.5**	45	17.3	-	12.5	-	**-4.8**
5 yr	1.30	1.1	1.9	Yes	0.2	-	**-1.7**	45	20.4	-	14.3	-	**-6.1**
10 yr	1.63	1.1	2.1	Yes	0.3	-	**-1.7**	45	22.9	-	15.9	-	**-7.0**
20 yr	1.99	1.1	2.2	Yes	0.4	-	**-1.8**	45	26.8	-	17.4	-	**-9.4**
50 yr	2.49	1.1	2.5	Yes	0.4	-	**-2.0**	45	31.7	-	19.6	-	**-12.1**
100 yr	2.90	1.1	2.6	Yes	0.5	-	**-2.1**	45	33.3	-	21.1	-	**-12.2**

Crossing 7 (HEC-RAS)

Flood	Discharge	Velocity (m/s)						Shear Stress (Nm^{-2})					
Frequency	(m^3s^{-1})	Permis.	Existing	Exceed	Proposed	Exceed	Diff.	Permis.	Existing	Exceed	Proposed	Exceed	Diff
2 yr	-	-	-	-	-	-	-	-	-	-	-	-	-
5 yr	49.40	0.8	1.3	Yes	0.9	Yes	**-0.4**	16	43.5	Yes	38.0	Yes	**-5.5**
10 yr	59.60	0.8	1.5	Yes	1.0	Yes	**-0.5**	16	48.1	Yes	41.5	Yes	**-6.6**
20 yr	74.10	0.8	1.8	Yes	1.2	Yes	**-0.6**	16	53.3	Yes	46.1	Yes	**-7.2**
50 yr	87.30	0.8	2.1	Yes	1.4	Yes	**-0.7**	16	58.2	Yes	50.1	Yes	**-8.1**
100 yr	97.60	0.8	2.3	Yes	1.5	Yes	**-0.8**	16	61.9	Yes	53.1	Yes	**-8.8**

Crossing 8 (HY-8)

Flood	Discharge	Velocity (m/s)						Shear Stress (Nm^{-2})					
Frequency	(m^3s^{-1})	Permis.	Existing	Exceed	Proposed	Exceed	Diff.	Permis.	Existing	Exceed	Proposed	Exceed	Diff
2 yr	0.35	0.9	2.1	Yes	0.4	-	**-1.7**	34	54.5	Yes	13.3	-	**-41.2**
5 yr	0.60	0.9	2.1	Yes	0.5	-	**-1.5**	34	57.1	Yes	16.6	-	**-40.4**
10 yr	0.81	0.9	2.1	Yes	0.7	-	**-1.4**	34	58.6	Yes	19.6	-	**-39.0**
20 yr	1.06	0.9	2.1	Yes	0.8	-	**-1.3**	34	59.7	Yes	21.6	-	**-38.0**
50 yr	1.47	0.9	2.1	Yes	1.0	Yes	**-1.2**	34	61.8	Yes	25.5	-	**-36.2**
100 yr	1.84	0.9	2.1	Yes	1.1	Yes	**-1.0**	34	63.0	Yes	28.3	-	**-34.7**

Crossing 9 (HY-8)

Flood	Discharge	Velocity (m/s)						Shear Stress (Nm^{-2})					
Frequency	(m^3s^{-1})	Permis.	Existing	Exceed	Proposed	Exceed	Diff.	Permis.	Existing	Exceed	Proposed	Exceed	Diff
2 yr	1.03	0.9	1.1	Yes	0.3	-	**-0.8**	34	15.2	-	11.9	-	**-3.3**
5 yr	1.73	0.9	1.3	Yes	0.4	-	**-0.9**	34	20.9	-	15.9	-	**-5.0**
10 yr	2.34	0.9	1.5	Yes	0.5	-	**-1.0**	34	25.4	-	19.8	-	**-5.6**
20 yr	3.06	0.9	1.6	Yes	0.5	-	**-1.1**	34	30.7	-	23.9	-	**-6.8**
50 yr	4.21	0.9	1.8	Yes	0.6	-	**-1.2**	34	38.7	Yes	30.1	-	**-8.6**
100 yr	5.26	0.9	1.9	Yes	0.6	-	**-1.3**	34	44.4	Yes	34.6	Yes	**-9.8**

Comparing Existing, Proposed, and Permissible Values of Velocity and Shear Stress

Crossing 10 (HY-8)

Flood Frequency	Discharge (m^3s^{-1})	Velocity (m/s)						Shear Stress (Nm^{-2})					
		Permis.	Existing	Exceed	Proposed	Exceed	Diff.	Permis.	Existing	Exceed	Proposed	Exceed	Diff
2 yr	0.10	0.9	2.0	Yes	0.2	-	**-1.8**	34	6.2	-	3.1	-	**-3.1**
5 yr	0.15	0.9	2.2	Yes	0.3	-	**-1.9**	34	7.7	-	3.7	-	**-4.0**
10 yr	0.18	0.9	2.3	Yes	0.3	-	**-2.0**	34	8.5	-	4.1	-	**-4.4**
20 yr	0.22	0.9	2.4	Yes	0.4	-	**-2.0**	34	9.7	-	4.4	-	**-5.2**
50 yr	0.27	0.9	2.4	Yes	0.4	-	**-2.0**	34	10.9	-	5.0	-	**-5.9**
100 yr	0.31	0.9	2.5	Yes	0.5	-	**-2.1**	34	11.8	-	5.3	-	**-6.5**

Crossing 11 Existing (HEC-RAS)

Flood Frequency	Discharge (m^3s^{-1})	Velocity (m/s)						Shear Stress (Nm^{-2})					
		Permis.	Existing	Exceed	Proposed	Exceed	Diff.	Permis.	Existing	Exceed	Proposed	Exceed	Diff
2 yr	1.71	1.1	0.4	**-**	0.5	**-**	**0.04**	45	6.9	-	6.2	-	**-0.8**
5 yr	2.62	1.1	0.6	-	0.6	-	**0.04**	45	8.5	-	7.4	-	**-1.1**
10 yr	3.35	1.1	0.7	-	0.7	-	**0.04**	45	9.9	-	8.4	-	**-1.4**
20 yr	4.17	1.1	0.8	-	0.8	-	**0.04**	45	11.4	-	9.7	-	**-1.7**
50 yr	5.40	1.1	1.0	-	1.0	-	**0.04**	45	13.1	-	11.6	-	**-1.5**
100 yr	6.46	1.1	1.1	Yes	1.1	Yes	**0.04**	45	14.7	-	12.8	-	**-1.9**

Crossing 11 Proposed Alternative 5C (HEC-RAS)

Flood Frequency	Discharge (m^3s^{-1})	Velocity (m/s)						Shear Stress (Nm^{-2})					
		Permis.	Existing	Exceed	Proposed	Exceed	Diff.	Permis.	Existing	Exceed	Proposed	Exceed	Diff
2 yr	1.73	1.1	0.4	-	0.2	-	**-0.2**	45	6.9	-	6.2	-	**-0.8**
5 yr	2.66	1.1	0.4	-	0.2	-	**-0.2**	45	8.5	-	7.4	-	**-1.1**
10 yr	3.40	1.1	0.5	-	0.3	-	**-0.2**	45	9.9	-	8.4	-	**-1.4**
20 yr	4.23	1.1	0.5	-	0.3	-	**-0.2**	45	11.4	-	9.7	-	**-1.7**
50 yr	5.47	1.1	0.5	-	0.4	-	**-0.2**	45	13.1	-	11.6	-	**-1.5**
100 yr	6.55	1.1	0.6	-	0.4	-	**-0.1**	45	14.7	-	12.8	-	**-1.9**

Comparing Existing, Proposed, and Permissible Values of Velocity and Shear Stress

Crossing 12 (HY-8)

Flood	Discharge	Velocity (m/s)						Shear Stress (Nm^{-2})					
Frequency	(m^3s^{-1})	Permis.	Existing	Exceed	Proposed	Exceed	Diff.	Permis.	Existing	Exceed	Proposed	Exceed	Diff
2 yr	0.03	0.9	0.3	-	0.3	-	**-0.01**	34	15.5	-	6.8	-	**-8.7**
5 yr	0.04	0.9	0.4	-	0.4	-	**0.00**	34	17.1	-	7.4	-	**-9.7**
10 yr	0.05	0.9	0.4	-	0.5	-	**0.01**	34	18.8	-	8.2	-	**-10.6**
20 yr	0.07	0.9	0.5	-	0.6	-	**0.04**	34	22.1	-	9.7	-	**-12.4**
50 yr	0.08	0.9	0.6	-	0.6	-	**0.06**	34	23.5	-	10.2	-	**-13.3**
100 yr	0.10	0.9	0.9	Yes	0.7	-	**-0.2**	34	35.0	Yes	11.2	-	**-23.8**

Crossing 13 (HY-8)

Flood	Discharge	Velocity (m/s)						Shear Stress (Nm^{-2})					
Frequency	(m^3s^{-1})	Permis.	Existing	Exceed	Proposed	Exceed	Diff.	Permis.	Existing	Exceed	Proposed	Exceed	Diff
2 yr	0.04	0.5	1.0	Yes	0.2	-	**-0.8**	18	6.2	-	2.9	-	**-3.3**
5 yr	0.06	0.5	1.1	Yes	0.3	-	**-0.9**	18	7.5	-	3.4	-	**-4.0**
10 yr	0.08	0.5	1.2	Yes	0.3	-	**-0.9**	18	8.8	-	3.9	-	**-4.9**
20 yr	0.10	0.5	1.3	Yes	0.4	-	**-0.9**	18	9.7	-	4.2	-	**-5.5**
50 yr	0.12	0.5	1.4	Yes	0.4	-	**-0.9**	18	10.7	-	4.6	-	**-6.1**
100 yr	0.15	0.5	1.3	Yes	0.5	Yes	**-0.9**	18	12.4	-	5.1	-	**-7.3**

Crossing 14 (HY-8)

Flood	Discharge	Velocity (m/s)						Shear Stress (Nm^{-2})					
Frequency	(m^3s^{-1})	Permis.	Existing	Exceed	Proposed	Exceed	Diff.	Permis.	Existing	Exceed	Proposed	Exceed	Diff
2 yr	1.10	1.1	1.8	Yes	0.5	-	**-1.3**	34	12.2	-	8.6	-	**-3.7**
5 yr	1.78	1.1	2.1	Yes	0.7	-	**-1.4**	34	16.2	-	10.3	-	**-6.0**
10 yr	2.28	1.1	2.3	Yes	0.8	-	**-1.5**	34	18.3	-	11.7	-	**-6.6**
20 yr	2.78	1.1	2.4	Yes	0.9	-	**-1.5**	34	21.7	-	13.0	-	**-8.7**
50 yr	3.48	1.1	2.6	Yes	1.1	Yes	**-1.6**	34	25.2	-	14.6	-	**-10.5**
100 yr	4.04	1.1	2.7	Yes	1.2	Yes	**-1.6**	34	26.4	-	15.7	-	**-10.7**

Crossing 15 (HEC-RAS)

Flood	Discharge	Velocity (m/s)						Shear Stress (Nm^{-2})					
Frequency	(m^3s^{-1})	Permis.	Existing	Exceed	Proposed	Exceed	Diff.	Permis.	Existing	Exceed	Proposed	Exceed	Diff
2 yr	-	-	-	-	-	-	-	-	-	-	-	-	-
5 yr	69.80	0.8	1.1	Yes	1.0	Yes	**-0.2**	16	12.9	Yes	12.1	Yes	**-0.7**
10 yr	84.50	0.8	1.3	Yes	1.1	Yes	**-0.2**	16	15.1	Yes	14.2	Yes	**-0.9**
20 yr	105.10	0.8	1.5	Yes	1.3	Yes	**-0.2**	16	15.8	Yes	14.8	Yes	**-1.0**
50 yr	122.60	0.8	1.7	Yes	1.4	Yes	**-0.3**	16	16.9	Yes	15.7	Yes	**-1.2**
100 yr	136.30	0.8	1.8	Yes	1.5	Yes	**-0.3**	16	17.5	Yes	16.1	Yes	**-1.5**

Crossing 16 (HY-8)

Flood	Discharge	Velocity (m/s)						Shear Stress (Nm^{-2})					
Frequency	(m^3s^{-1})	Permis.	Existing	Exceed	Proposed	Exceed	Diff.	Permis.	Existing	Exceed	Proposed	Exceed	Diff
2 yr	0.29	1.2	1.3	Yes	0.4	-	**-1.0**	57	7.9	-	6.3	-	**-1.7**
5 yr	0.41	1.2	1.5	Yes	0.5	-	**-1.0**	57	9.2	-	7.0	-	**-2.2**
10 yr	0.61	1.2	1.7	Yes	0.6	-	**-1.1**	57	10.9	-	8.4	-	**-2.5**
20 yr	0.75	1.2	1.8	Yes	0.7	-	**-1.2**	57	12.4	-	9.6	-	**-2.8**
50 yr	0.78	1.2	1.9	Yes	0.7	-	**-1.2**	57	12.7	-	9.8	-	**-2.9**
100 yr	1.02	1.2	2.0	Yes	0.8	-	**-1.2**	57	14.1	-	10.8	-	**-3.3**

Crossing 17 (HY-8)

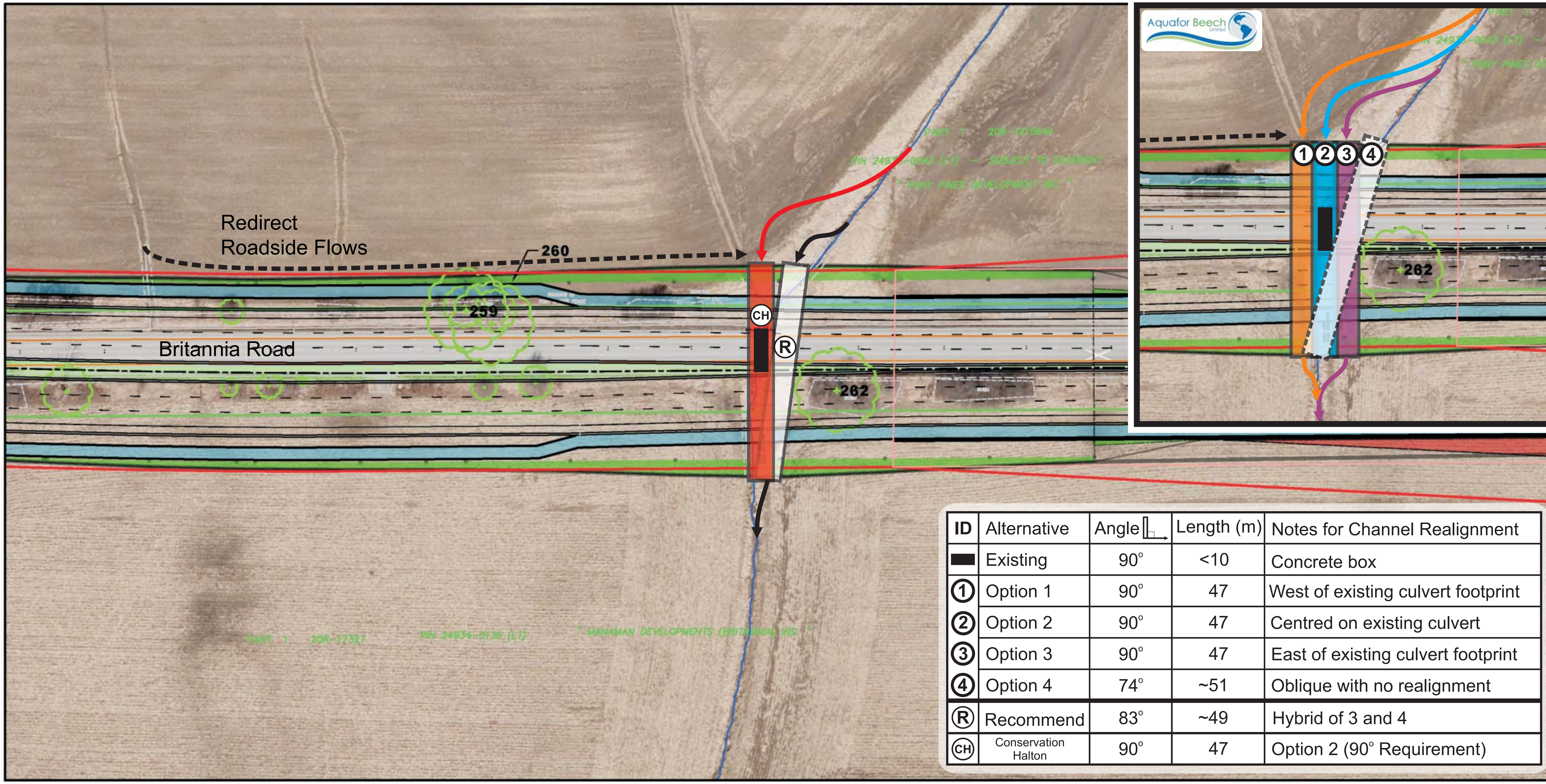
Flood	Discharge	Velocity (m/s)						Shear Stress (Nm^{-2})					
Frequency	(m^3s^{-1})	Permis.	Existing	Exceed	Proposed	Exceed	Diff.	Permis.	Existing	Exceed	Proposed	Exceed	Diff
2 yr	1.92	1.2	2.8	Yes	0.5	-	**-2.3**	57	8.8	-	5.2	-	**-3.6**
5 yr	3.01	1.2	2.9	Yes	0.6	-	**-2.3**	57	9.7	-	6.3	-	**-3.4**
10 yr	4.46	1.2	3.0	Yes	0.8	-	**-2.2**	57	10.8	-	7.6	-	**-3.3**
20 yr	5.15	1.2	3.0	Yes	0.9	-	**-2.2**	57	11.4	-	8.3	-	**-3.1**
50 yr	5.20	1.2	3.0	Yes	0.9	-	**-2.2**	57	11.5	-	8.4	-	**-3.1**
100 yr	6.51	1.2	3.0	Yes	1.0	-	**-2.1**	57	12.3	-	9.2	-	**-3.1**

Crossing 18 (HY-8)

Flood Frequency	Discharge (m^3s^{-1})	Velocity (m/s)						Shear Stress (Nm^{-2})					
		Permis.	Existing	Exceed	Proposed	Exceed	Diff.	Permis.	Existing	Exceed	Proposed	Exceed	Diff
2 yr	0.68	1.2	0.2	-	0.2	-	**0.0**	57	4.6	-	4.6	-	**0.0**
5 yr	1.04	1.2	0.2	-	0.2	-	**0.0**	57	5.2	-	5.2	-	**0.0**
10 yr	1.46	1.2	0.3	-	0.3	-	**0.0**	57	6.1	-	6.1	-	**0.0**
20 yr	1.74	1.2	0.3	-	0.3	-	**0.0**	57	6.7	-	6.7	-	**0.0**
50 yr	1.81	1.2	0.3	-	0.3	-	**0.0**	57	6.9	-	6.9	-	**0.0**
100 yr	2.24	1.2	0.4	-	0.4	-	**0.0**	57	7.4	-	7.4	-	**0.0**

Appendix C

Culvert Alignment Recommendations



ID	Alternative	Angle	Length (m)	Notes for Channel Realignment
▬	Existing	90°	<10	Concrete box
①	Option 1	90°	47	West of existing culvert footprint
②	Option 2	90°	47	Centred on existing culvert
③	Option 3	90°	47	East of existing culvert footprint
④	Option 4	74°	~51	Oblique with no realignment
Ⓡ	Recommend	83°	~49	Hybrid of 3 and 4
CH	Conservation Halton	90°	47	Option 2 (90° Requirement)

Culvert Alignment Recommendations - Alterative Analysis

Halton REGION

CLASS ENVIRONMENTAL ASSESSMENT STUDY

BRITANNIA ROAD

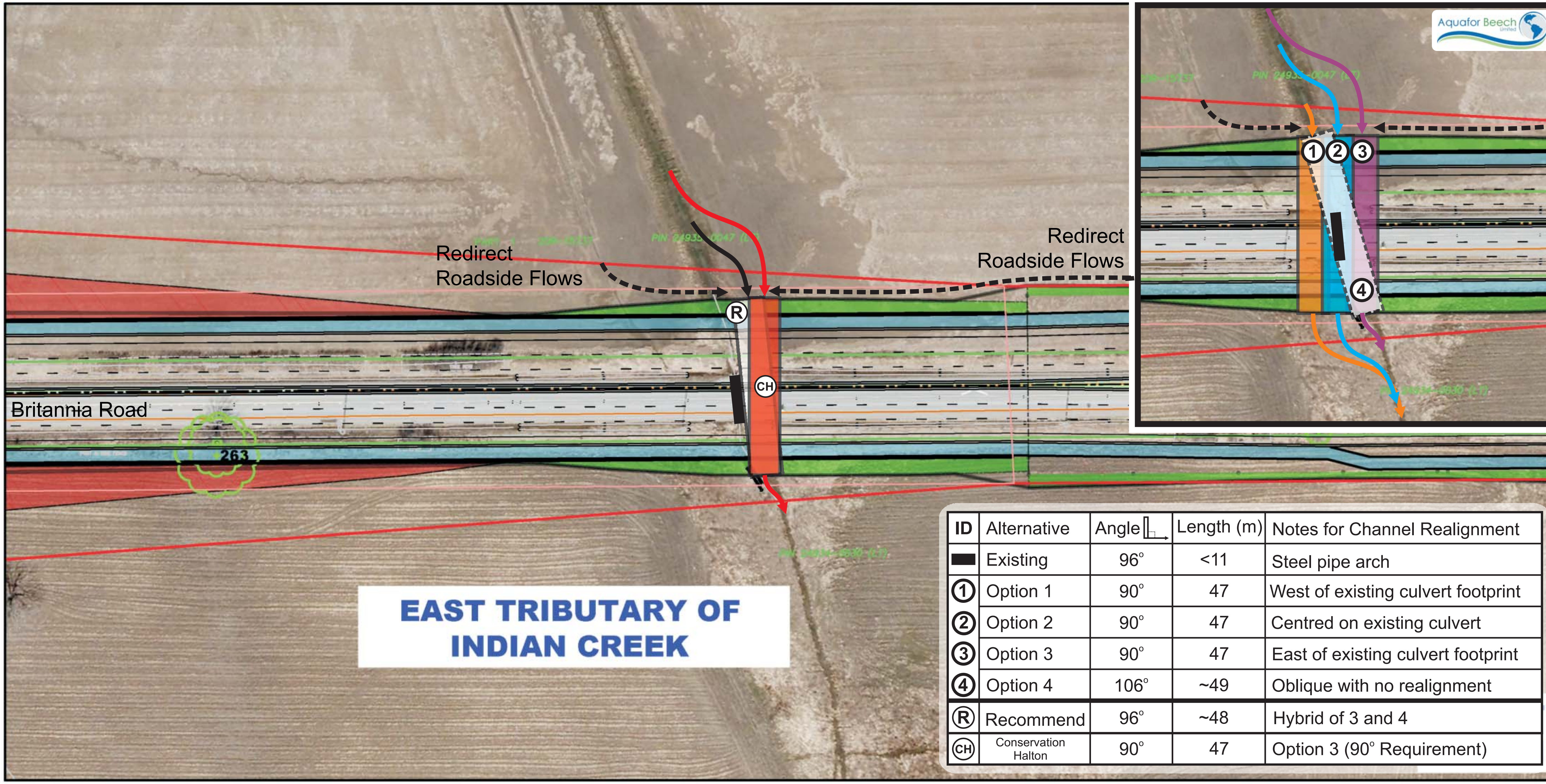
(From Tremaine Road to Highway 407)

Delcan

Dec, 2012

Watercourse Crossing #1

SCALE: 1:1000



ID	Alternative	Angle	Length (m)	Notes for Channel Realignment
▬	Existing	96°	<11	Steel pipe arch
①	Option 1	90°	47	West of existing culvert footprint
②	Option 2	90°	47	Centred on existing culvert
③	Option 3	90°	47	East of existing culvert footprint
④	Option 4	106°	~49	Oblique with no realignment
Ⓡ	Recommend	96°	~48	Hybrid of 3 and 4
CH	Conservation Halton	90°	47	Option 3 (90° Requirement)

Culvert Alignment Recommendations - Alterative Analysis

Halton REGION

CLASS ENVIRONMENTAL ASSESSMENT STUDY

BRITANNIA ROAD

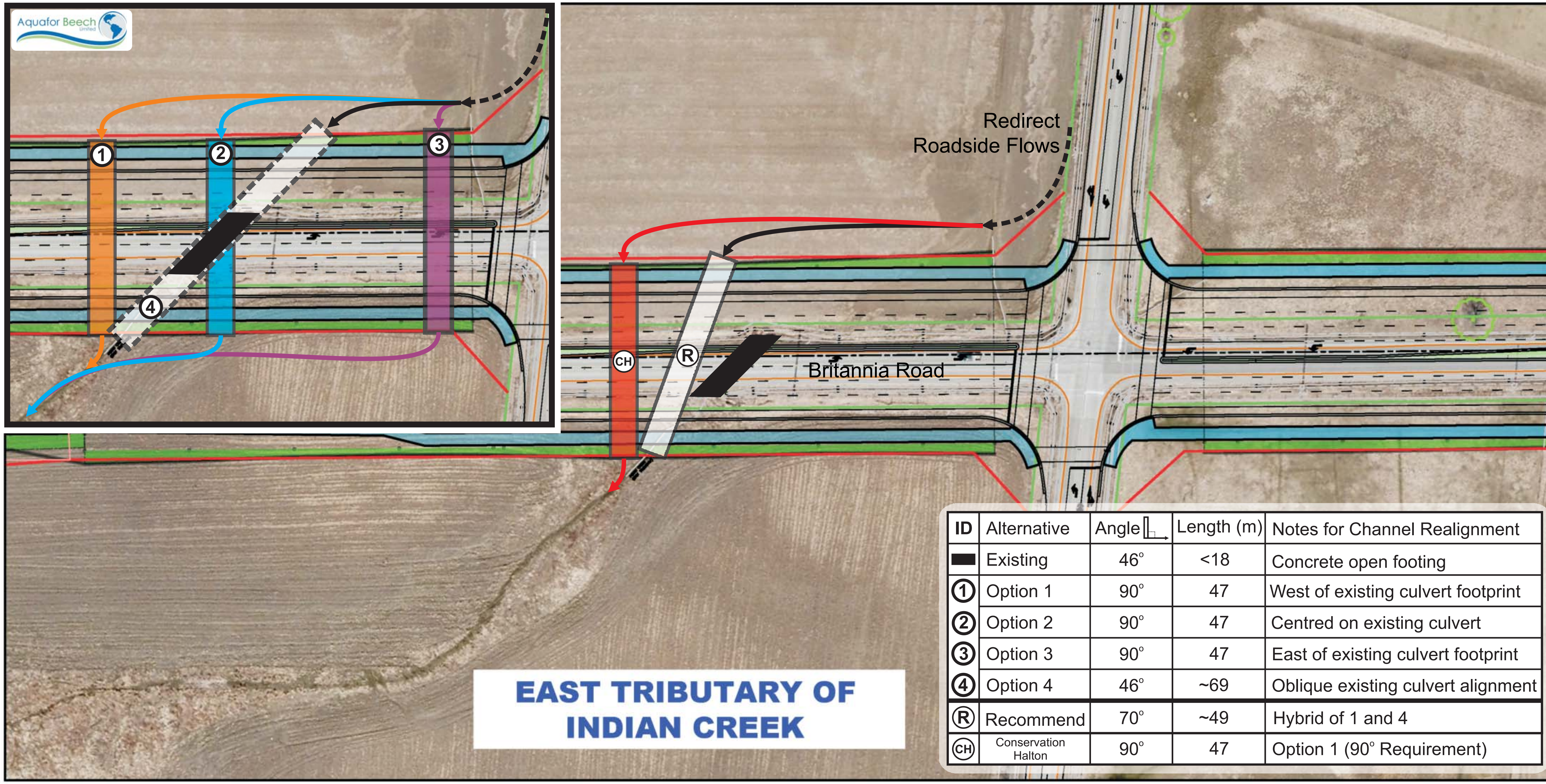
(From Tremaine Road to Highway 407)

Watercourse Crossing #2

Delcan

Dec, 2012

SCALE: 1:1000



ID	Alternative	Angle	Length (m)	Notes for Channel Realignment
▬	Existing	46°	<18	Concrete open footing
①	Option 1	90°	47	West of existing culvert footprint
②	Option 2	90°	47	Centred on existing culvert
③	Option 3	90°	47	East of existing culvert footprint
④	Option 4	46°	~69	Oblique existing culvert alignment
Ⓡ	Recommend	70°	~49	Hybrid of 1 and 4
CH	Conservation Halton	90°	47	Option 1 (90° Requirement)

Culvert Alignment Recommendations - Alterative Analysis

Halton REGION

CLASS ENVIRONMENTAL ASSESSMENT STUDY

BRITANNIA ROAD

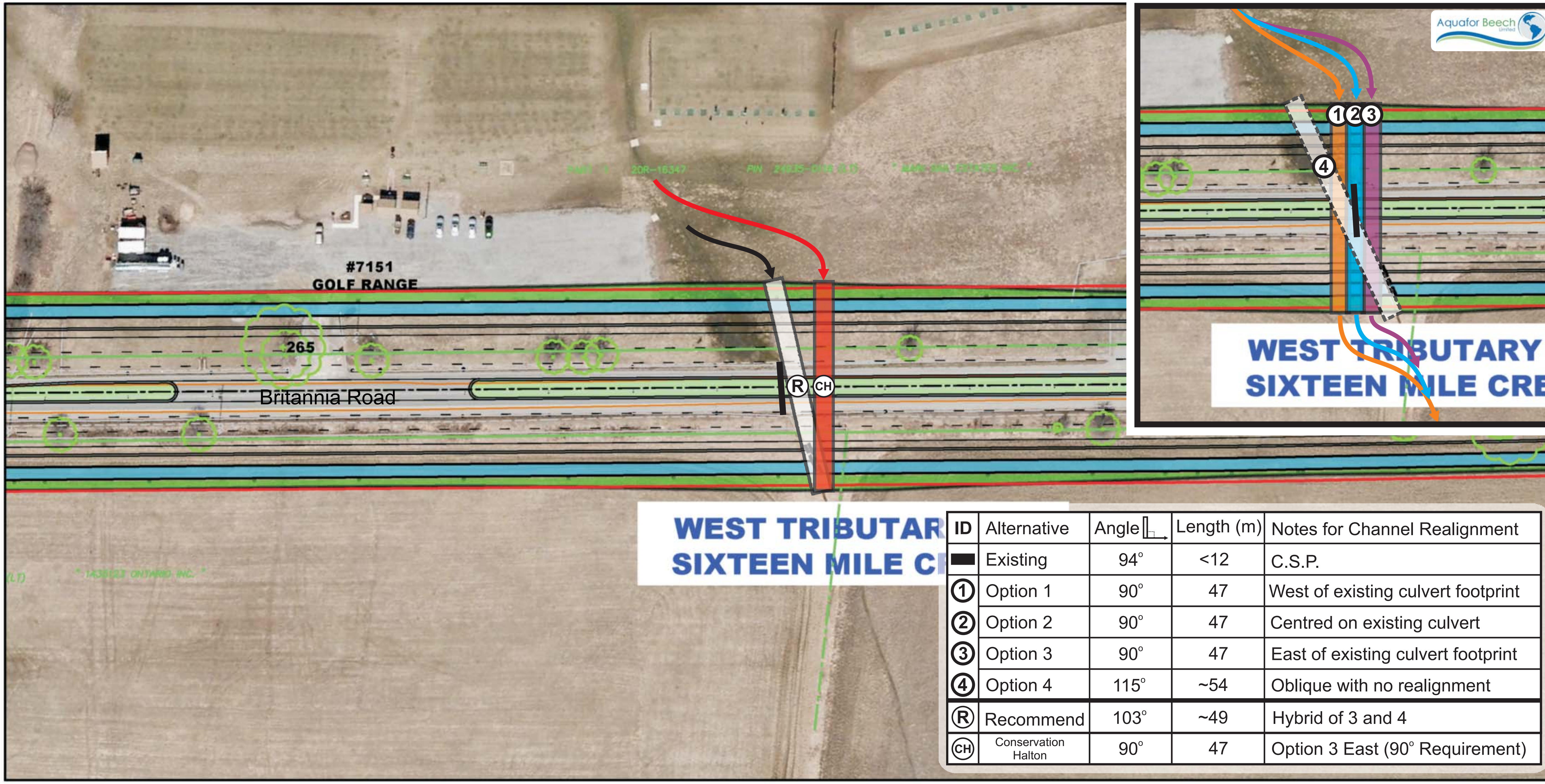
(From Tremaine Road to Highway 407)

Delcan

Dec, 2012

Watercourse Crossing #3

SCALE: 1:1000



ID	Alternative	Angle	Length (m)	Notes for Channel Realignment
▬	Existing	94°	<12	C.S.P.
①	Option 1	90°	47	West of existing culvert footprint
②	Option 2	90°	47	Centred on existing culvert
③	Option 3	90°	47	East of existing culvert footprint
④	Option 4	115°	~54	Oblique with no realignment
Ⓡ	Recommend	103°	~49	Hybrid of 3 and 4
CH	Conservation Halton	90°	47	Option 3 East (90° Requirement)

Culvert Alignment Recommendations - Alterative Analysis

Halton REGION

CLASS ENVIRONMENTAL ASSESSMENT STUDY

BRITANNIA ROAD

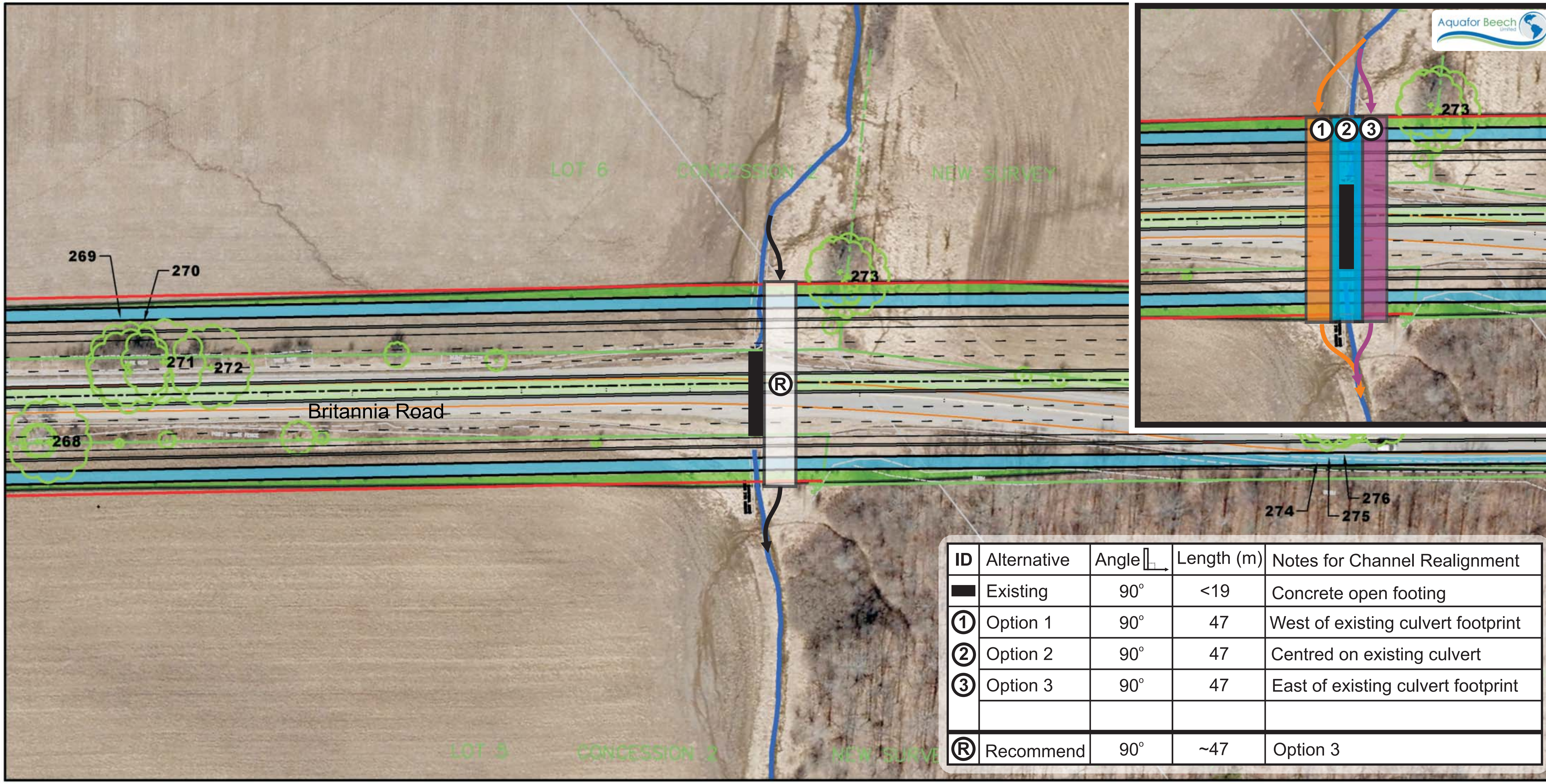
(From Tremaine Road to Highway 407)

Watercourse Crossing #4

Delcan

Dec, 2012

SCALE: 1:1000



ID	Alternative	Angle	Length (m)	Notes for Channel Realignment
▬	Existing	90°	<19	Concrete open footing
①	Option 1	90°	47	West of existing culvert footprint
②	Option 2	90°	47	Centred on existing culvert
③	Option 3	90°	47	East of existing culvert footprint
Ⓡ	Recommend	90°	~47	Option 3

Culvert Alignment Recommendations - Alterative Analysis

Halton REGION

CLASS ENVIRONMENTAL ASSESSMENT STUDY

BRITANNIA ROAD

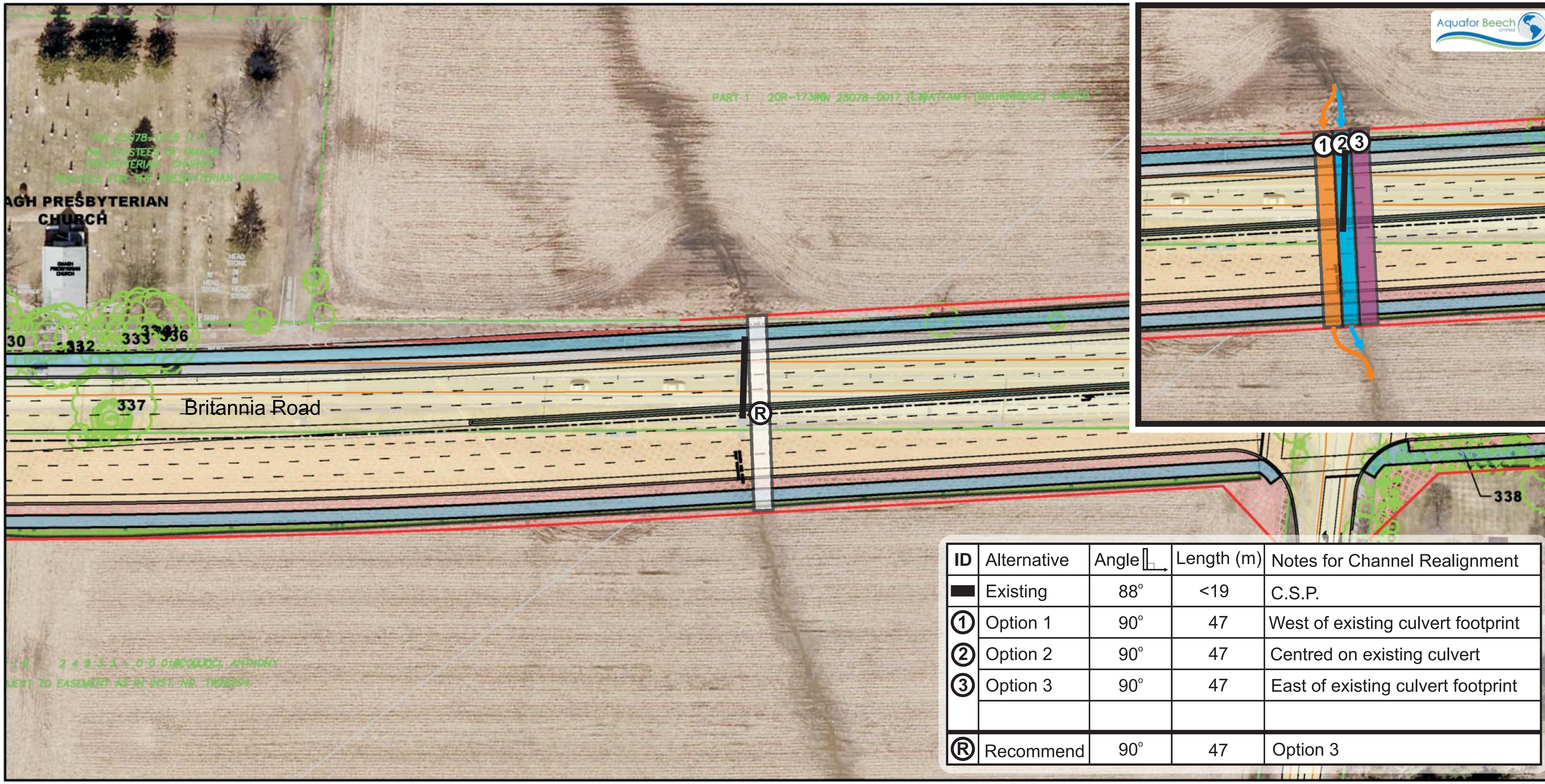
(From Tremaine Road to Highway 407)

Delcan

Dec, 2012

Watercourse Crossing #5

SCALE: 1:1000



ID	Alternative	Angle	Length (m)	Notes for Channel Realignment
▬	Existing	88°	<19	C.S.P.
①	Option 1	90°	47	West of existing culvert footprint
②	Option 2	90°	47	Centred on existing culvert
③	Option 3	90°	47	East of existing culvert footprint
Ⓡ	Recommend	90°	47	Option 3

Culvert Alignment Recommendations - Alterative Analysis

Halton REGION

CLASS ENVIRONMENTAL ASSESSMENT STUDY

BRITANNIA ROAD

(From Tremaine Road to Highway 407)

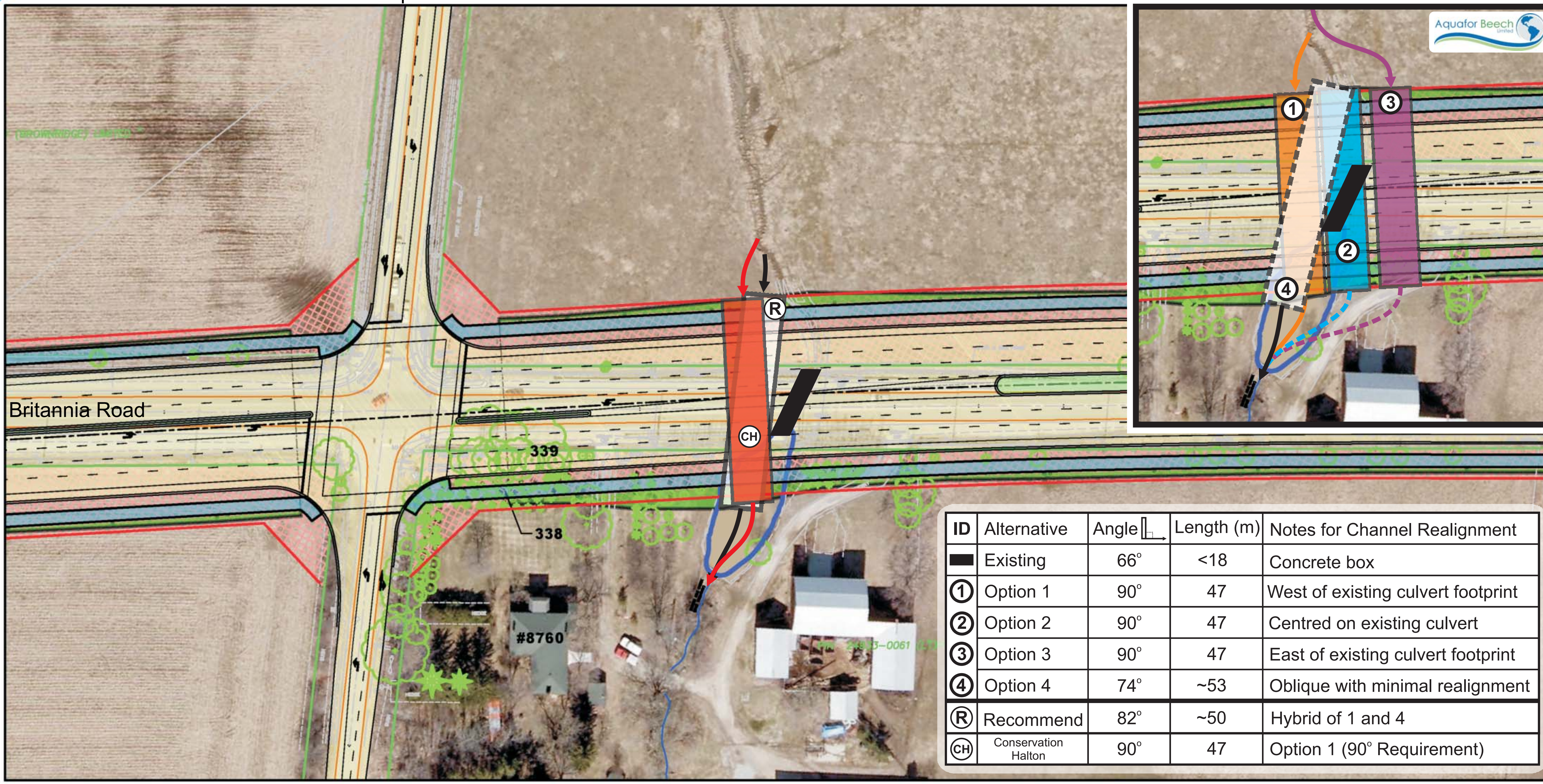
Delcan

Dec, 2012

Watercourse Crossing #8

SCALE: 1:1000

Thompson Road



ID	Alternative	Angle	Length (m)	Notes for Channel Realignment
▬	Existing	66°	<18	Concrete box
①	Option 1	90°	47	West of existing culvert footprint
②	Option 2	90°	47	Centred on existing culvert
③	Option 3	90°	47	East of existing culvert footprint
④	Option 4	74°	~53	Oblique with minimal realignment
Ⓡ	Recommend	82°	~50	Hybrid of 1 and 4
(CH)	Conservation Halton	90°	47	Option 1 (90° Requirement)

Culvert Alignment Recommendations - Alterative Analysis

Halton REGION

CLASS ENVIRONMENTAL ASSESSMENT STUDY

BRITANNIA ROAD

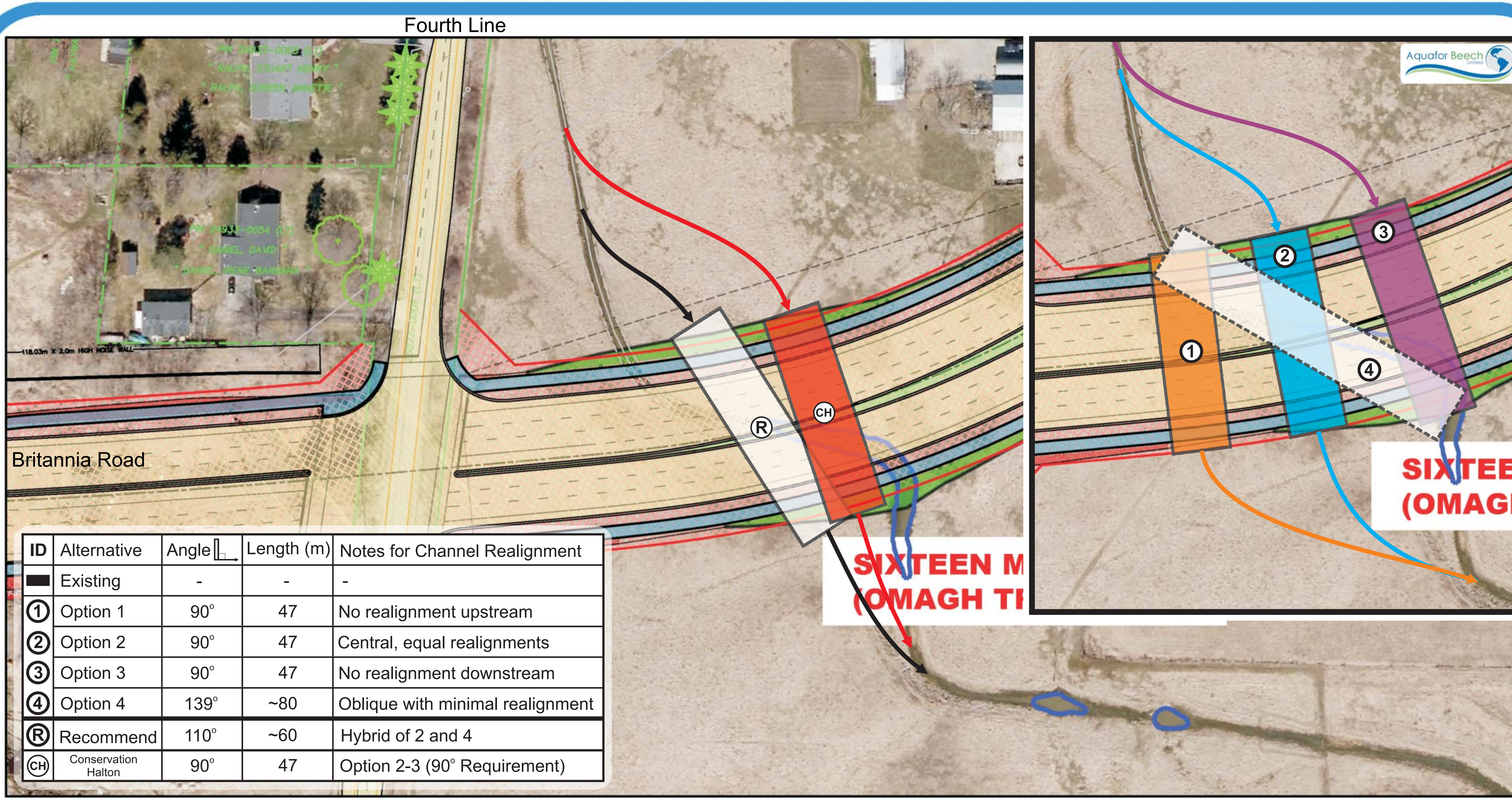
(From Tremaine Road to Highway 407)

Dec, 2012

Watercourse Crossing #9

Delcan

SCALE: 1:1000



ID	Alternative	Angle	Length (m)	Notes for Channel Realignment
▬	Existing	-	-	-
①	Option 1	90°	47	No realignment upstream
②	Option 2	90°	47	Central, equal realignments
③	Option 3	90°	47	No realignment downstream
④	Option 4	139°	~80	Oblique with minimal realignment
Ⓡ	Recommend	110°	~60	Hybrid of 2 and 4
(CH)	Conservation Halton	90°	47	Option 2-3 (90° Requirement)

Culvert Alignment Recommendations - Alterative Analysis

Halton REGION

CLASS ENVIRONMENTAL ASSESSMENT STUDY

BRITANNIA ROAD

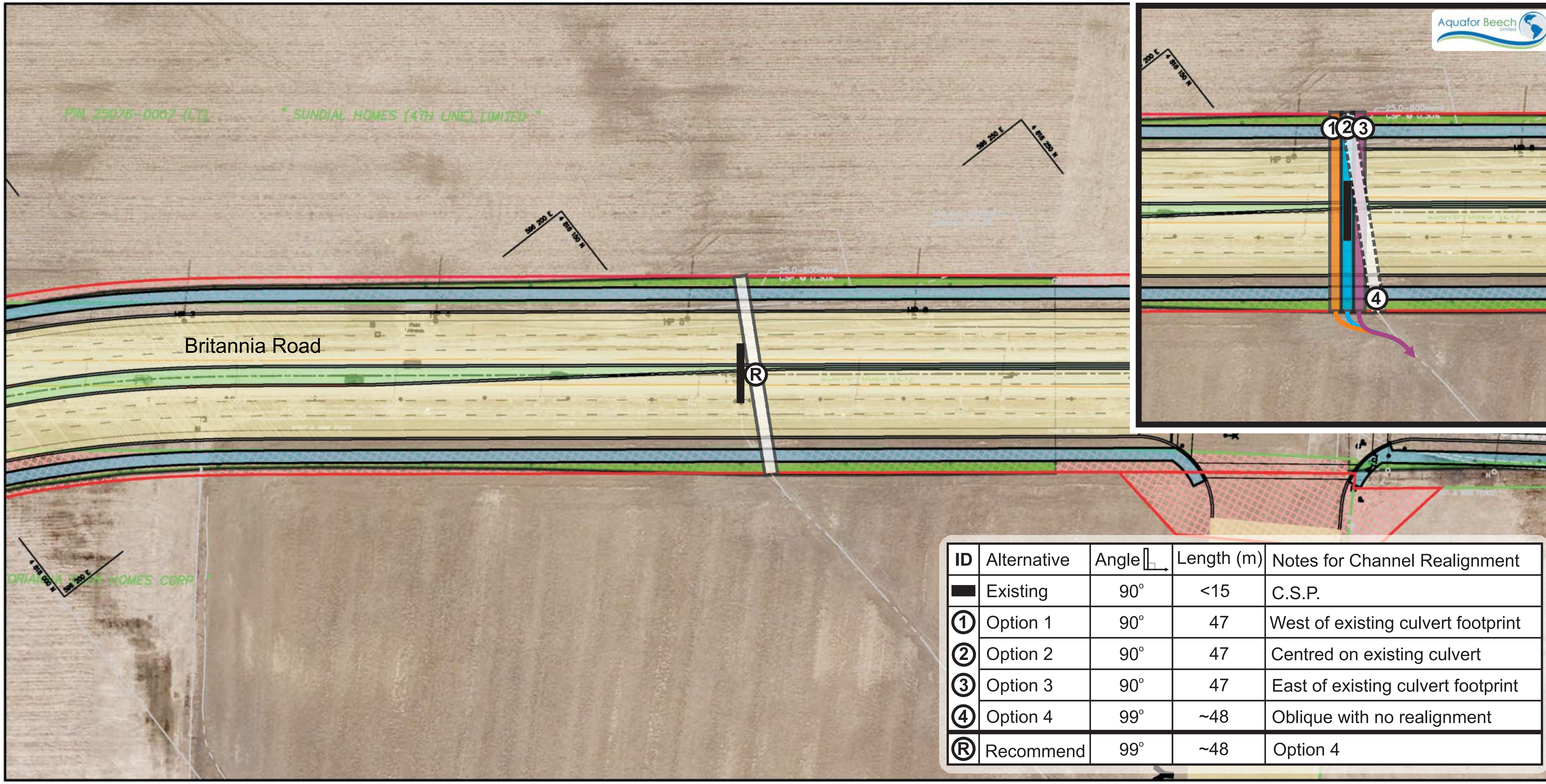
(From Tremaine Road to Highway 407)

Watercourse Crossing #11

Delcan

Dec, 2012

SCALE: 1:1000



ID	Alternative	Angle	Length (m)	Notes for Channel Realignment
▬	Existing	90°	<15	C.S.P.
①	Option 1	90°	47	West of existing culvert footprint
②	Option 2	90°	47	Centred on existing culvert
③	Option 3	90°	47	East of existing culvert footprint
④	Option 4	99°	~48	Oblique with no realignment
Ⓡ	Recommend	99°	~48	Option 4

Culvert Alignment Recommendations - Alterative Analysis

Halton REGION

CLASS ENVIRONMENTAL ASSESSMENT STUDY

BRITANNIA ROAD

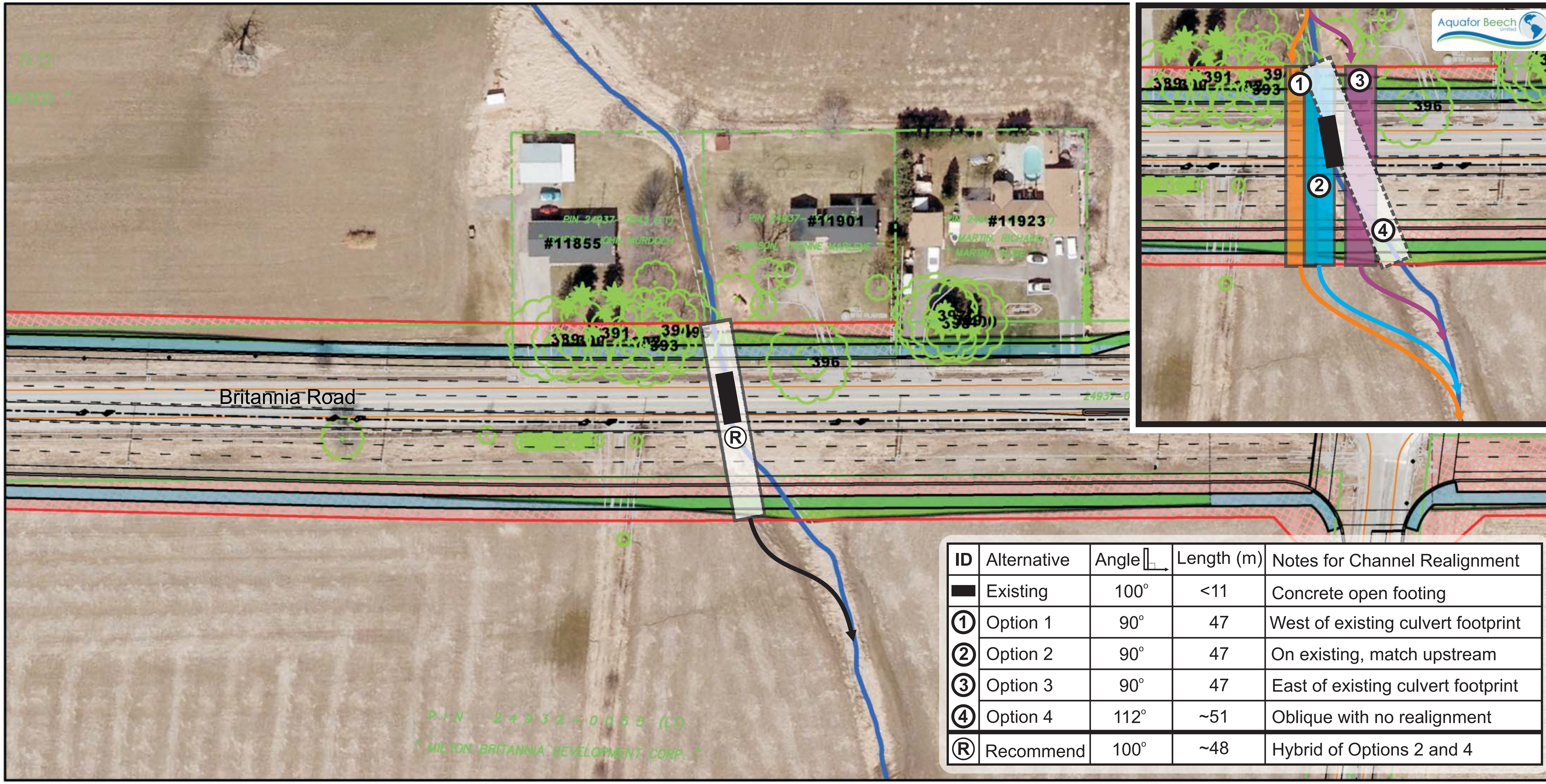
(From Tremaine Road to Highway 407)

Watercourse Crossing #12

Delcan

Dec, 2012

SCALE: 1:1000



ID	Alternative	Angle	Length (m)	Notes for Channel Realignment
▬	Existing	100°	<11	Concrete open footing
①	Option 1	90°	47	West of existing culvert footprint
②	Option 2	90°	47	On existing, match upstream
③	Option 3	90°	47	East of existing culvert footprint
④	Option 4	112°	~51	Oblique with no realignment
Ⓡ	Recommend	100°	~48	Hybrid of Options 2 and 4

Culvert Alignment Recommendations - Alterative Analysis

Halton REGION

CLASS ENVIRONMENTAL ASSESSMENT STUDY

BRITANNIA ROAD

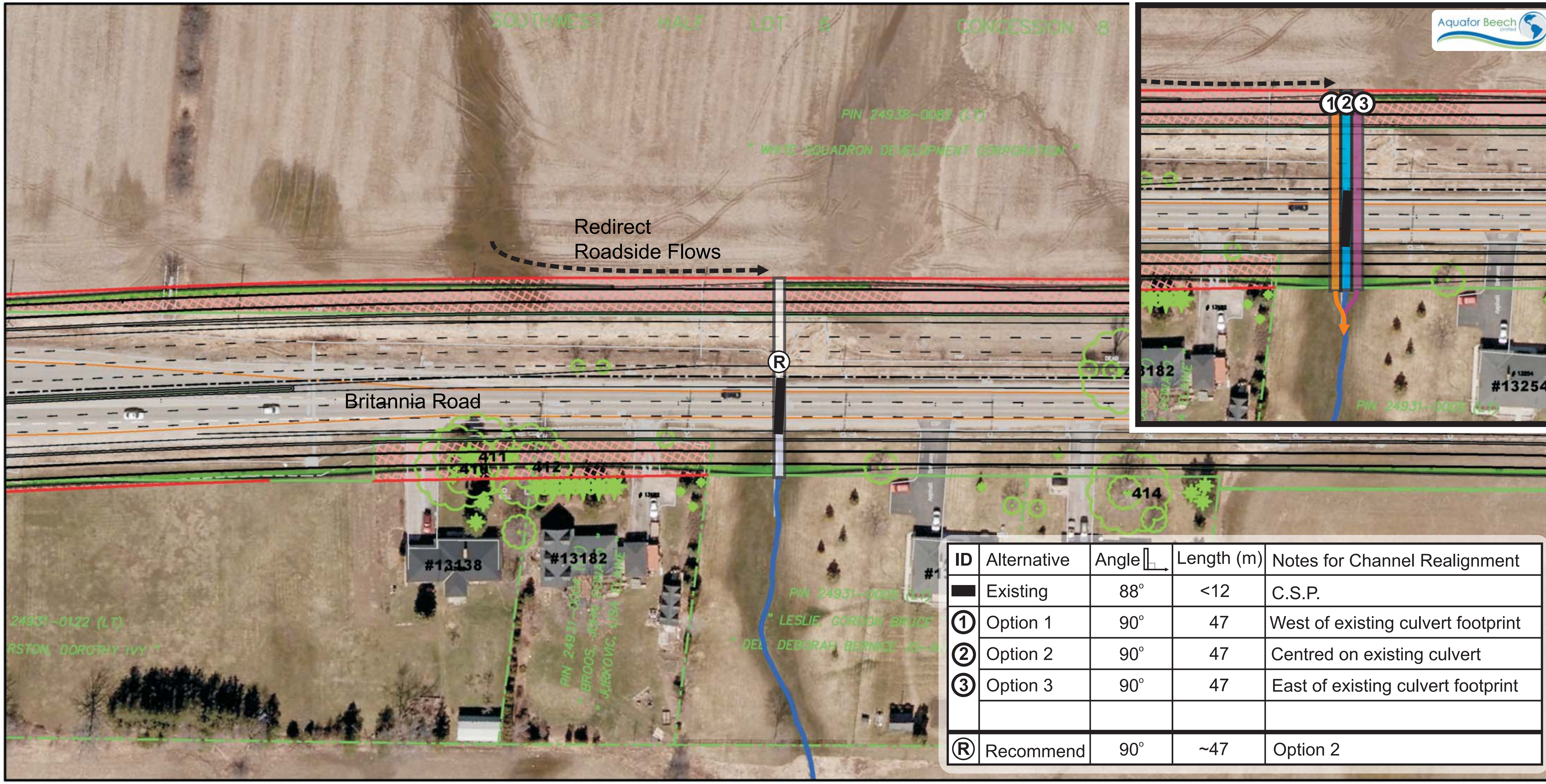
(From Tremaine Road to Highway 407)

Dec, 2012

Watercourse Crossing #14

SCALE: 1:1000

Delcan



ID	Alternative	Angle	Length (m)	Notes for Channel Realignment
▬	Existing	88°	<12	C.S.P.
①	Option 1	90°	47	West of existing culvert footprint
②	Option 2	90°	47	Centred on existing culvert
③	Option 3	90°	47	East of existing culvert footprint
Ⓡ	Recommend	90°	~47	Option 2

Culvert Alignment Recommendations - Alterative Analysis

Halton REGION

CLASS ENVIRONMENTAL ASSESSMENT STUDY

BRITANNIA ROAD

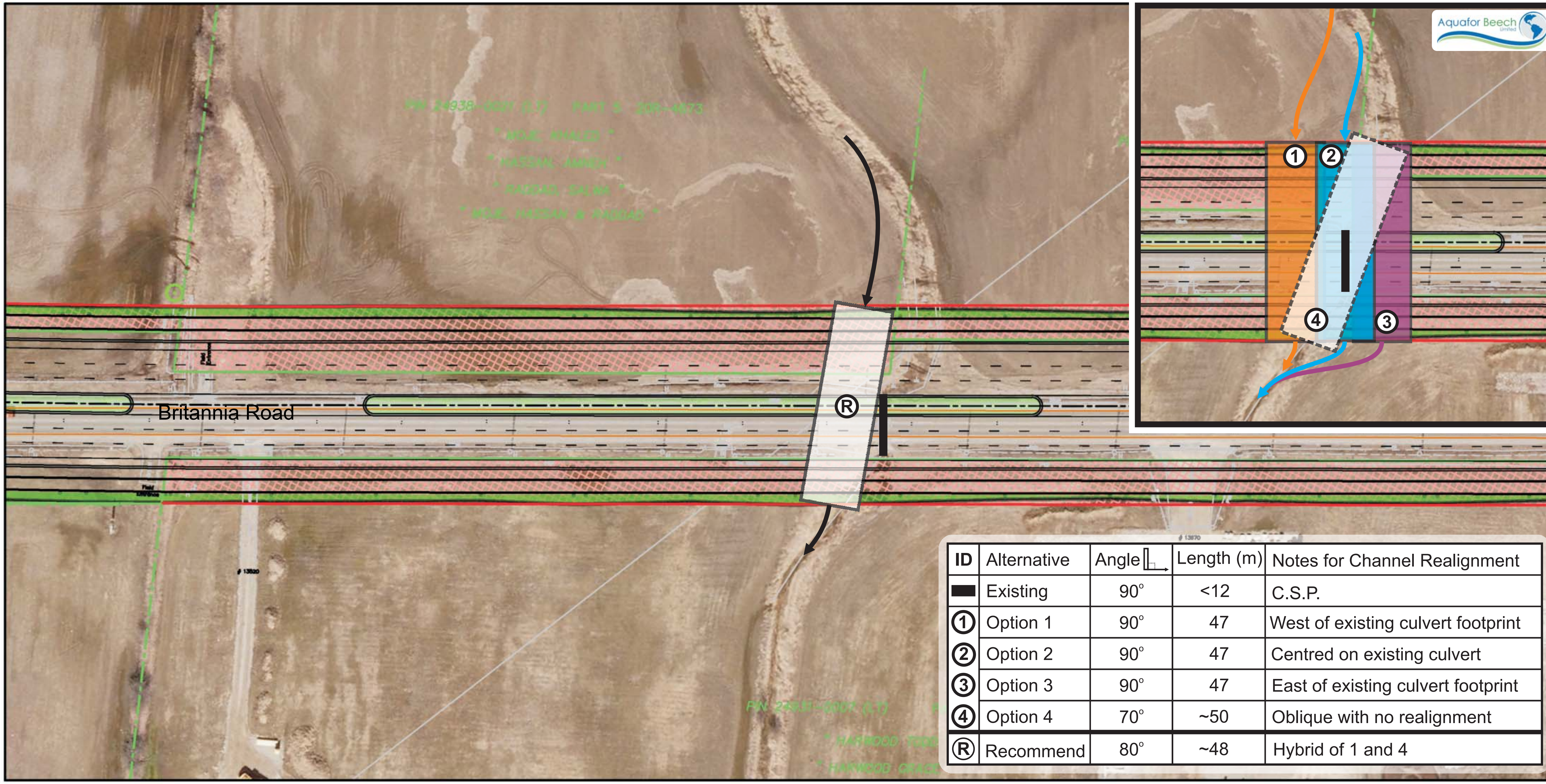
(From Tremaine Road to Highway 407)

Delcan

Dec, 2012

Watercourse Crossing #16

SCALE: 1:1000



ID	Alternative	Angle	Length (m)	Notes for Channel Realignment
▬	Existing	90°	<12	C.S.P.
①	Option 1	90°	47	West of existing culvert footprint
②	Option 2	90°	47	Centred on existing culvert
③	Option 3	90°	47	East of existing culvert footprint
④	Option 4	70°	~50	Oblique with no realignment
®	Recommend	80°	~48	Hybrid of 1 and 4

Culvert Alignment Recommendations - Alterative Analysis

Halton REGION

CLASS ENVIRONMENTAL ASSESSMENT STUDY

BRITANNIA ROAD

(From Tremaine Road to Highway 407)

Watercourse Crossing #17

Delcan

Dec, 2012

SCALE: 1:1000

Appendix D

Response to Comments

PROTECTING THE NATURAL ENVIRONMENT FROM LAKE TO ESCARPMENT

CONSERVATION HALTON

2596 Britannia Road West
Burlington ON L7P 0G3
905.336.1158 Fax 905.336.7014
conservationhalton.ca

October 25, 2012

Ms Alicia Jakatis
Region of Halton
1151 Bronte Road
Oakville, ON
L6M 3L1

Dear Ms Jakatis:

Re: Britannia Road – Tremaine to Highway 407
Class Environmental Assessment
Technical Background Reports
CH File: MPR 558

Staff of Conservation Halton appreciate the opportunity to review the draft technical background reports in advance of the Region finalizing the above noted Environmental Assessment (EA).

We have reviewed the following information:

- *Minutes of Meeting with Conservation Halton – Britannia Road (Regional Road 6) Transportation Corridor Improvements, Tremaine Road (Regional Road 22) to Highway 407 Class Environmental Assessment Study*, meeting date October 1, 2012;
- *Britannia Road Transportation Corridor Improvements – Tremaine Road to Highway 407 – Supporting Technical Report: Hydraulic Analyses of Stream Crossings and Stormwater Management Alternatives Assessment- Draft Final Report*, prepared by Aquafor Beech, dated August 2012;
- *Britannia Road Transportation Corridor Improvements; Tremaine Road to Highway 407 Class EA Study – Environmental Study Report – Fluvial Geomorphology Study*, prepared by Aquafor Beech, dated August 2012; and,
- *Britannia Road Transportation Corridor Improvements: Tremaine Road to Highway 407 Class EA Study – Terrestrial and Aquatic Resources*, prepared by Aquafor Beech, dated August 2012.

Hydraulic Analyses of Stream Crossings and Stormwater Management Alternatives

Section 3.1 Flood Flows

Staff appreciate that flows for the full range of design storms from the 1:2-1:100 year and Regional Storm events have been presented in Table 2. At present staff have focused on the Catchment Drainage Area and Regional Storm flow and have not completed a detailed review of the 2-100 year storms. Staff have confirmed, however, that the Existing and Proposed Development 2-100 year flows presented in the FSEMS report [Reference Table 3.1: Pre-Development Land Use (No Development) Frequency Flows (m^3/s) and Table 4.6: Proposed Land Use with Proposed SWM Criteria (m^3/s)] are generally consistent with the values presented in Table 2. Staff appreciate that the more conservative of the existing vs. proposed flows were generally selected for the 2-100 year flows. As our review has indicated significant changes to the Regional Storm flows considered in several areas, staff have deferred a more detailed review of the flow analysis for the frequent storm return periods to subsequent submissions.

Please review the following significant drainage area/flow concerns associated with Table 2 and the appended hydraulic modeling. Please revise/refine as required:

- For outlets 1, 2, and 3, Table 2 of the study indicates a total drainage area capture of 163.3ha, however Conservation Halton's records indicate a total drainage area of 332ha. Staff completed a more detailed review of the information for this area, and flag the following:

  - For Outlet 1 - The FSEMS for Boyne (Drawing 2 of 3) outlines a total drainage area of 137.6ha post development between Louis St. Laurent and Britannia Road, and as per Figure 3.4 of the SIS Area 8 Study (Urbantec 2009) completed for the drainage area north of Louis St. Laurent, an additional 29.4 ha of drainage area is directed to Outlet 1, resulting in a total drainage area of 167ha to Outlet 1.

  - For Outlet 2 – The FSEMS outlines a total drainage area of 115.7ha post development between Louis St. Laurent and Britannia Road (Reference Drawing 2 of 3), and as per Figure 3.4 of the SIS Area 8 Study (Urbantec 2009) completed for the drainage area north of Louis St. Laurent, an additional 28.0 ha of drainage area is directed to Outlet 2, resulting in a total drainage area of 143.7ha.

  - For Outlet 3 - The FSEMS combines the drainage area to this outlet with Outlet 2, however Conservation Halton information indicates that this drainage area previously received runoff from approximately 70ha. Additional details supporting the proposed 9.5ha existing conditions drainage area for catchment 3 is required, to ensure the culvert is appropriately sized in advance of future development.

  The total drainage area indicated to Outlets 1, 2 and 3 between the FSEMS and SIS 8 is approximately 310ha under post development conditions. Given minor drainage shifts that have proceeded following upstream development, staff are satisfied that a post development drainage area of 167ha and 143.7ha will be sufficient for design purposes for Outlets 1, and 2 and 3 (combined). Staff also note that based on Table 4.6 of the FSEMS, the Regional Storm flow for the proposed condition is currently modeled at $21m^3/s$ at Outlet 1 as opposed to the $17.4m^3/s$ existing condition listed by Aquafor Beech in Table 2 and the 15.77 m^3/s that appeared to have been considered in the modeling. For Outlet 2, Table 4.6 indicates that the proposed Regional Storm flow will be $18.6m^3/s$ as opposed to the existing condition of $16.7m^3/s$ identified in the tables and modeling for Outlet 2. While Conservation Halton has yet to endorse the FSEMS, staff recommend that the Region work towards the worst case existing condition flows for the 1:2 year to 1:100 year return events and post development conditions for the Regional Storm event for Outlets 1 and 2, and existing condition flows for Outlet 3.

- Outlet 4 – Staff were unable to identify the source of the 18.9ha drainage area referenced for this catchment. Based on FSEMS Figures 1 and 2, the 16.93ha pre-development drainage area would appear to have the largest flow contribution to this structure. The indicated flow of $7.5m^3/s$ considered in the analysis appears to be very conservative for the existing area identified in the FSEMS. Provided there are not other sizing considerations, this culvert may be further optimized through detailed design.

- Outlet 5 - The FSEMS highlights a drainage area of 106.1ha between Louis St. Laurent and Britannia Road under the more conservative post development conditions (per Figure 2 of 3 of AMEC's March 2011 study). Based on DSEL's design brief for Stormwater Management Pond S47, an additional drainage area of 57.6ha contributes flow to this catchment north of Louis St. Laurent, resulting in a total drainage area of 163.7ha to Outlet 5. The total flow contribution to Node 5 listed in the table and considered in the appended hydraulic modeling appears inconsistent with the FSEMS findings for other similarly sized catchments (i.e. at Node 1). Further, Table 4.6 (Proposed Conditions with SWM) of the FSEMS, indicates that the post-development regional flow is anticipated to be $17.06m^3/s$.

- Outlet 5A – The FSEMS outlines a total drainage area of 16.15ha to this outlet under existing conditions (reference Figure 1), and 9.12 ha under post-development. Given the uncertainty associated with the timing of future development, staff request consideration of sizing the culvert for Outlet 5a based on the larger drainage area associated with the existing conditions, unless it can be demonstrated that anticipated post development flow conditions will exceed the existing conditions flows.

- Outlet 6 – The input file WEST 3 from the FSEMS appears to indicate a total drainage area of 222.0ha to Outlet 6, with a drainage area of 117.9ha upstream of Louis St. Laurent. For Node 6, the modeled existing condition flow of $16.00m^3/s$ in the FSEMS appears to be disproportionately low, and is lower than the Proposed Condition Flow (reference Table 4.6) of $19.42m^3/s$.

- Outlet 7 – While staff note that the drainage area listed is slightly larger than expected, the Regional Storm flow listed in Table 2 and considered in the hydraulic modeling appears to be off by an order of magnitude.

- Outlet 9 – The drainage area listed in Table 4 does not appear to include the 35.31ha of external drainage area identified in the HSPF model West 2. Staff believe the total drainage area to Outlet 9 to be approximately 138ha, as per AMEC's modeling. We also note that based on Table 4.6 in the FSEMS, the proposed condition flow at Node 2.802 will be $18.75m^3/s$, which is considerably higher than the $11.7m^3/s$ identified in Table 2.

- Outlet 11 – Based on the FSEMS a drainage area of 237ha has been identified at this point. This includes the 12.56 ha drainage area identified at Outlet 10. Staff note that the FSEMS drainage area considered in the HSPF appeared to ignore any flow contribution north of Louis St. Laurent. This is in error, as Pond 3 (Hawthorne Village Phase 3) outlets to a siphon and contributes 37.9ha of drainage area to Outlet 11. Additional drainage area to the siphon from the woodlot and remnant parcel west of Thompson Road was also identified as draining to this feature. While staff are still working to pull together records to confirm the external drainage area north and east of the Pond 3 outlet, as well as details of the siphon design – including peak flows, we are able to provide a 1:100 year flow of $1.81m^3/s$ that was used to size the culvert under Hepburn Road through the woodlot upstream of the Pond 3 outfall (reference Stantec - June 8, 2004 design brief – *CH File A/04/M/21*). If requested, staff will pull additional information to confirm the total drainage area to this feature. Unfortunately, as this drainage impacts the Omagh Tributary, addressing the change in flows associated with this change in drainage area may not be deferred to detailed design.

- Outlets 14, 16, 17 and 18 – Please provide additional detail (including catchment area plans, and all calculations) for the drainage area and flows determined for Outlets 14, 16, 17 and 18. The table below provides a summary of the drainage areas Conservation Halton has derived through GIS based on a 2002 TIN.

Table 1 – Comparison of Drainage Area

Node	Drainage Area (ha)	
	Table 2 (Aquafor Beech)	Conservation Halton
14	38.5	107
16	10.3	40
17	227	344
18	96	136

Section 3.2 – Culvert/Bridge Capacity Estimates

Staff are not supportive of maintaining general model parameters consistent with up and downstream modeling in an updated model, should the up and downstream parameters not be deemed typical for the site. As discussed at the October 1, 2012 meeting, the proponent is required to complete localized updates to the model to reflect current/future conditions. There is not a requirement to update the entire model, however updates should extend a sufficient distance up and downstream to ensure that any hydraulic instabilities that may result from the change in parameters occur outside of the area of interest associated with this study. Localized changes to both the existing and proposed conditions may be required.

Section 3.2.2 – Proposed Structures

Staff would have no objection to the Region locally shifting drainage to eliminate several of the smaller non-regulated drainage features that would ultimately be eliminated with the future development in Phase 3 Milton, provided the future Permit drawings clearly show how drainage has been re-directed, and that such redirections do not negatively impact flooding and erosion on upstream properties, or if a temporary increase is noted, provided the upstream landowners provide their consent. This would need to be coordinated with the upstream landowners and should ideally take place as part of the Subwatershed Impact Studies prepared by the landowners in conjunction with the detailed design by the Region of Britannia Road.

Table 4

Table 4 indicates that for Crossing 3 there will be a decrease in effective opening area of the culvert from 4.2m^2 to 3.66m^2. While the hydraulic criteria required as per the MTO may be met, there may be negative upstream flooding implications as compared to the existing conditions. Should a larger upstream drainage area be confirmed, staff will require a detailed evaluation of the proposed structure's hydraulic and geomorphologic impacts over the full range of storm events before staff may support this reduction in culvert size. This may be deferred to detailed design, subject to the EA including a commitment requiring the Region to submit a Permit application that demonstrates the proposed grading and drainage changes will not negatively impact flooding or erosion hazards under the full range of design storms.

The proposed crossing size at Node 6 is not consistent with the sizing used for the upstream crossing of this system at Louis St. Laurent. The upstream Louis St. Laurent Crossing was much wider at 10.2 m wide by 2.8 m high. It is important that the EA consider the design requirements of the upstream crossings to ensure consistency along the system. See additional comments under "Aquatic Assessment" below.

The minimum culvert width noted for Crossing 1 in Appendix G of the FSEMS was a 4.2m wide by 0.75m high culvert. This culvert would have a smaller open area, but larger width than the culvert currently proposed in Table 4. Staff request further discussion with respect to the requirements of the

FSEMS and Conceptual Fisheries Compensation Plan for Boyne and the culvert sizing associated with the Britannia Road EA. Any proposal to reduce culvert sizes will require detailed analysis and will need to be justified from both a hydraulic, fisheries and terrestrial movement perspective.

There are substantial differences between the existing and proposed road elevations shown in Table 4. Staff require confirmation that the analysis considered changes in the road profile at any adjacent road sags (i.e. major flow paths) which are not always co-incident with the culvert placement. Please modify the analysis if required, and include conceptual road plan and profile drawings with any subsequent submissions.

Section 3.3 – Flood Impacts

Based on Table 5, crossings 2, 4, 5A, 7, and 15 will result in an increase in the regulatory storm floodplain or predicted Regional Storm water level, while crossings 7, 15 and 16 will result in flooding increases under the 1:50 and 1:100 year return events.

At Crossing 2, the proposed increase in road grade will result in an approximately 0.6m increase in the Regulatory Flood Plain. Given the flat local topography this change is not confined within the existing regulated limit. While this increase does not appear to impact any existing habitable residences, there may be other development implications. Therefore, please note that staff will require written acknowledgement and acceptance of the proposed floodplain change from all impacted landowners. This acknowledgement/acceptance may be deferred to detailed design, but must form part of the permit submission.

Based on the limited information available for Crossing 4, the water level increase has the potential to impact an existing habitable structure at 7151 Britannia Road. Given the limited upstream drainage area, and the limitations of the modeling completed, staff cannot confirm whether or not the adjacent existing structures may be impacted. Staff do not regulate the feature associated with the crossing, and therefore only recommend that the Region consider impacts to upstream properties through the detailed design process.

Table 7 indicates that Option 5B would result in an increase in the modeled Regional Storm flood elevations at cross-sections 34-36. If this increase impacts any existing habitable structures, Conservation Halton will be unable to support Option 5B. Please ensure a figure detailing the locations of the hydraulic cross sections for each of the options considered is provided as part of the final EA documentation submitted for review.

Appendix A - Staff note that for the PCSWMM study the Regional Storm flow was not modeled based on the full 36 hours of antecedent rainfall, rather a shortened 12 hour period depositing 24mm of rainfall was modeled. Please modify the model to account for the full 73mm of rainfall over the initial 36 hours of the storm.

Appendix B

Staff were unable to obtain a digital copy of the hydraulic modeling supporting the existing and proposed hydraulic structure capacities, as Aquafor Beech determined that since the models had been changed following issuance of the August 2012 document, a digital copy of the hydraulic model would only further confuse the comments. Staff require that a digital copy of the hydraulic modeling be included as part of the forthcoming draft ESR submission, and are willing to defer detailed review of the hydraulic modeling to that submission, provided there is an opportunity to finalize any changes required before the filing of the EA. Staff are also open to the receipt of a secondary hydraulics submission.

Please label the provided output relative to the structure naming convention adopted in the report.

As the submitted materials do not provide sufficient detail to support a conceptual design, (i.e. staff will require the submission of a preliminary plan and profile drawing along Britannia Road, a figure showing the location of all significant hydraulic cross sections, digital copies of the relevant hydraulic models, etc.) staff cannot confirm the sufficiency of the hydraulic sizing at this time. Further comments may be forthcoming following submission of the draft ESR.

The hydraulic design report does not clearly present the proposed grading changes (if any) along Britannia Road, which may have key impacts on the hydraulics. Staff will require that the EA commit to submitting a permit application that demonstrates the proposed grading and drainage changes will not negatively impact flooding or erosion hazards under the full range of design storms. Please note that Conservation Halton cannot support any works that would negatively impact the flooding or erosion on an existing habitable structure. Increases in flooding and/or erosion extending onto private property and not impacting an existing habitable structure will be considered on a case by case basis, and if necessary, may be permitted provided all impacted landowners provide written acknowledgement and consent to the change and there is no negative impact to safe access and egress.

Fluvial Geomorphology Study

Table 2

It is suggested that bankfull channel measurements be collected at one pool, one riffle and one run feature both upstream and downstream of each road crossing structure. A conservative approach would be to size the crossing structure based on the largest bankfull measurement taken at each respective crossing.

The table notes the bankfull width for each crossing, and the photos in Appendix A appear to indicate site investigations spanned several days and different hydrologic conditions. Please provide a brief description on the timing of the field visits, and detail when the Top of Bank Width was defined, with respect to flow conditions.

For Crossings 14, 17, and 18, the proposed culvert sizes will not be sufficient to contain the average bankfull width documented in Table 2 of the Fluvial Geomorphology Report. Geomorphic input on the appropriateness of these culvert sizes, relative to maintaining natural channel function and the erosion risk to the structure is required. See additional comments below regarding the draft Conceptual Fisheries Compensation Plan requirements for watercourse crossings in the Boyne Secondary Plan Area.

Table 4 - Staff note an error in Table 4 with respect to Crossing 16. Please revise.

Table 6

Table 6 indicates that the proposed conditions for 9 of the 19 culverts analyzed may have limited stability during some storm events, as the proposed velocity exceeds the estimated permissible velocity. Staff are particularly concerned with respect to Crossings 8, 10 (under option 5B), and 14, as these exceed the permissible velocities on a more frequent basis. Please provide additional discussion as to the impacts and mitigation measures associated with the velocity increases, and identify appropriate commitments to be addressed through the detailed design. Is it anticipated that larger culvert sizes will be required for all eight crossings listed in Table 6? Will permissible velocity estimates be refined? At this stage, staff need confirmation that at a conceptual level crossings have been sized to allow maintenance of the natural channel process.

Terrestrial and Aquatic Resources

For all intermittent watercourses within the study area, it is preferred that watercourses be realigned if necessary to facilitate the entry of the watercourse at a perpendicular angle to Britannia Road. This is suggested to reduce the length of the culverts underneath Britannia Road as much as possible. Staff recognize that this will require significant coordination between the Region, Town, Conservation Halton and the landowners north and south of Britannia Road. The landowners in the Boyne Secondary Plan Area are proposing on-line Regional Storm controls. This could have a significant impact on the crossing designs and will need to be discussed in detail.

Staff recommend that the report should include discussion as to how construction equipment will access the main Sixteen Mile Creek Valley, particularly as it relates to impacts on terrestrial features. Mapping of the 12 regionally significant plant species would be of assistance in this regard.

A comprehensive commitments section should be added to the report to provide clarity on which recommendations will be carried forward to detailed design.

Table 1 - The breeding bird surveys were conducted on consecutive days which increases the likelihood of some species being missed and makes it more difficult to confirm the breeding status of birds observed. As such, a conservative approach to determining breeding status would be appropriate. We also note the fall dates of the vegetation inventory would not have captured the full species diversity present in the study area. Additional spring/summer inventory work should be conducted at detailed design within the limits of disturbance to ensure that no species of conservation concern will be impacted by the works.

Section 3.3.4, Historic Records of Provincially Significant Fauna - It should be noted that, in addition to being provincially rare (S2), the habitat of Jefferson dominated polyploids (i.e. LJJ) is protected under the *Endangered Species Act*. Direction on additional survey requirements for Jefferson Salamander should be obtained from MNR. By copy of this letter, staff are providing our comments to Aurora McAllister, MNR Aurora District.

Section 3.3.6, Significant Wildlife Habitat, page 33 and Section 4.1.1.4, Significant Species and Habitat, page 37- It is staff's understanding that the habitat for Threatened species (e.g. Bobolink) would not also be considered under the significant wildlife habitat policies of the PPS.

Section 4.1.1.1, Flora and Vegetation Communities - This section lacks a discussion about the relative impacts of expanding to the north or to the south at the main branch of Sixteen Mile Creek. It should include a summary of the vegetation community and any significant features present, and make a recommendation as to which option would be preferred from a terrestrial habitat perspective.

Section 4.1.1.2, Tree Survey - Please clarify the statement, "There are six trees along the proposed alignment of Britannia Road that appear to be outside of the new proposed property line." How many of the 221 trees surveyed within the new property line will be removed?

Section 4.1.1.3, Wetlands - It is stated in the text that no wetland will be removed adjacent to the significant woodland because of the shift of the road alignment to the south, however the drawing appears to indicate that the sidewalk/trail will swing north across the meadow marsh, resulting in a loss of about 7-11 m of wetland along its length. Please clarify. It should also be noted that meadow marsh habitat in the vicinity of Crossings 2 and 3 will be lost.

Section 4.1.1.4, Significant Species and Habitat, Significant Woodlands, page 36 – this section states, "Intrusion into these significant woodlands to avoid encroaching on private property would need to be discussed with Conservation Halton at Detail Design." We note that this was discussed briefly at the October 1, 2012 meeting. At that time CH terrestrial ecology staff were not present and, as such, staff deferred comment in this regard until such time as those staff had reviewed the terrestrial assessment. As noted on October 1, 2012, staff appreciate that an Environmental Assessment is intended to balance the impacts to various environmental impacts including the natural environment and social environment however; based on the information contained within the report, there is insufficient data available to allow staff to determine what the anticipated impacts to the woodlands would be. Staff recommend that this be discussed in greater detail at the next agency meeting.

Section 4.3, Endangered Species Act Protection - Staff note that the two letters sent from MNR (July 5, 2011 to Brent Tegler and August 29, 2011 to Chris Lorenz) related to species at risk and natural areas reference different species. The August letter requests additional information on the proposal to allow MNR to determine whether an ESA permit would be required. Has this information been provided to MNR and if so, what was the outcome? The text in the report indicates that the need for ESA permits will be determined at detailed design. We strongly recommend that these matters be resolved at the earliest possible opportunity given that the approvals process under the ESA can be lengthy.

Section 4.5.1.1, Terrestrial Impacts - Please quantify the number of tree removals required.

Table 5 - Staff appreciate the thorough and comprehensive form of this table.

Section 5.1, Terrestrial Resources - All tree removals should be undertaken outside of the breeding bird season, not just those adjacent to hayfields. This commitment should be included in the ESR.

Section 5.2, Wildlife Crossing Structures - enhanced wildlife crossings should be implemented at Crossings 1, 2, 5, 6, 7 and 11, as identified in the Boyne FSEMS, and we also support the recommendation of Aquafor Beech for enhanced wildlife crossings at crossings 15, 17 and 18. We note that proposed culvert sizing is available in the Hydraulic Analyses of Stream Crossings and Stormwater Management Alternatives Assessment report. The Terrestrial and Aquatic Resources report should cross-reference these values, in consideration of the wetted width of the respective watercourses, to determine whether adequate freeboard will be available along the sides to allow for use by terrestrial wildlife.

Table 6 - outlines the fish collection records held by Conservation Halton and the results of fish collections performed by LGL Limited (2007; 2008), C. Portt and Associates (2008) and Aquafor Beech Ltd. (2011). Staff note the following:

- Conservation Halton's fish community database indicates that the following additional 14 fish species have been documented in the vicinity of Crossing # 7 and Britannia Road: Brown Trout, Mottled Sculpin, Fantail Darter, Rainbow Trout, Rosyface Shiner, River Chub, Stonecat, Rock Bass, Pumpkinseed, Bluntnose Minnow, Johnny Darter, Rainbow Smelt, Yellow Perch, Fathead Minnow.
- Conservation Halton's fish community database indicates that 19 additional fish species are documented to use the Lower Middle Branch of Sixteen Mile Creek that crosses under Britannia Road at Crossing # 15: Rainbow Trout, Chinook Salmon, Stonecat, Black Crappie, Golden Shiner, Longnose Dace, Fantail Darter, Silver Shiner, Northern Pike, Northern Hognose Sucker, Blacknose Dace, Rosyface Shiner, River Chub, Sea Lamprey, Brook Stickleback, Fathead Minnow, Largemouth Bass, Bluegill Sunfish.

Please add these fish species to the appropriate column in Table 6.

Section 5.2 Aquatic Resources

A number of the fish species in the study area are considered to be cold and cool water fish species. Regardless of this situation, timing windows are usually based on the timing of spawning of the fish species present in the study area. Please note the first bullet point in this section, which refers to the timing window applicable for the watercourses in the study area.

Staff request a commitment within the ESR to undertake all work in dry conditions and that no work will be undertaken in wet conditions within the watercourses in the study area for this project.

Appendix 6 - Please add a column to this table to indicate which trees will be removed and which will be retained.

Appendix 8 Watercourse Crossing Photo Documentation

Please ensure that each photograph in this section is labelled with respect to the direction in which the photo is being taken, its location upstream or downstream of Britannia Road and the culvert number that it has been taken at. Please use the same numerals used in Figure 1: Study Area Stream Crossings in the Hydraulic Analyses of Stream Crossings and SWM Alternatives Document.

As noted in previous meetings, there are a number of background documents that have been prepared by AMEC on behalf of the Town of Milton for the Boyne Survey. Although none of the documents have been endorsed by Conservation Halton yet, they contain important direction for works within the Secondary Plan Area, including watercourse crossings. With respect to watercourse crossing width requirements, Section 4.3 of the draft Conceptual Fisheries Compensation Plan for the Boyne Survey, prepared by AMEC, dated March 2011 provides detailed requirements that should be incorporated into any watercourse crossing. A portion of Section 4.3 is outlined below however, we recommend that a complete review of the draft CFCP and FSEMS be undertaken to ensure consistency:

> *4.3.1 Stream Crossings (Preliminary Design Components – Road/Railway Crossings)*
>
> *The estimated size of each hydraulic opening for the respective crossing has been based on the estimated minimum conveyance geometry to sustain natural channel form at each location and approximate 25 year flow rate. The final size determination is to be completed as part of future SIS's and site plan applications, based on a detailed assessment of hydrologic and hydraulic conditions, and required road/railway geometrics including conveyance of the Regulatory flood event, which will likely overtop most local roadways.*

In addition, Table 4.8 in the draft CFCP identifies estimated hydraulic structures within the Boyne Survey.

Section 4.3.1 of the draft CFCP also notes the following:

> *Each of the road crossings should be designed and constructed to provide the following:*
>
> *(a) Natural substrate through open footing design or through the use of an embedded culvert invert to a depth of 0.5m preferred (minimum 0.3m);*
> *(b) Low flow channel through crossing (this may involve staggering the depth of culvert inverts i.e. multiple culvert crossings to promote low flow through a single culvert.);*
> *(c) Minimum span opening recommended to be approximately twice the proposed bankfull width in order to maintain natural channel form.*

Finally, Section 4.3.1 of the draft CFCP also provides direction with respect to enhanced wildlife crossings. Please consult this document. Staff would be pleased to discuss any concerns/questions that the Study Team has with these recommendations.

Appendix 8, Fish Passage, page 67 - fish passage must be assured at all crossings, when the watercourse is considered fish habitat.

The no in-water work timing window for Crossings # 7 and # 15 is from Sept. 15 to July 1 of any year. The no in water work timing window that applies to the remainder of the watercourses is from April 1 and July 1 of any year.

Figures

It is unclear why tree numbers are provided on only one of the long drawings. Please clarify.

For future submissions, it would be helpful to number figures and provide more descriptive titles for ease of reference.

Detailed Design

At detailed design staff will require geomorphic input on the culvert sizing and design and channel re-alignment for each regulated watercourse. We also request that a commitment be made to the incorporation of single span open bottom crossings spanning 2 times the bankfull channel width, with the provision for wildlife passage, as per the draft Conceptual Fisheries Compensation Plan.

Please include a commitment to obtain a Permit under Ontario Regulation162/06 for each section of roadway crossing through a regulated area – which is currently approximated as:

- Crossing 1 – 600 m length along Britannia Road From Tremaine Road Easterly.
- Crossing 2 – From the Railway to Bronte Road/First Line
- Crossing 5 – From 830m west of Reg. Road 25 to 580m west of Reg. Road 25
- Crossing 6 - From Reg. Road 25 to 270m west of Reg. Road 25
- Crossing 7 – From 240 m west of Sixteen Mile Creek to 170 m East of Sixteen Mile Creek
- Crossing 8 – A 70 m width centred on the watercourse downstream
- Crossing 9 – From Thompson Road to 250 m west of Thompson Road
- Crossing 10 – Approximately 330 m length centred on the watercourse
- Crossing 11 – From 60m west to 90 m east of Fourth Line
- Crossing 14 – From 190 m west of Sixth Line to 120 m west of Sixth Line
- Crossing 15 – From 320m west of Trafalgar Road to 40 m west of Trafalgar Road
- Crossing 16 – a 30 m width centered on the watercourse
- Crossing 17 - From 660 m west of Eight Line to 360 m east of Eighth Line
- Crossing 18 – From 745 m west of the 407 to the end of the study area

As the regulated area varies across the differing alignments through Omagh, the Region and their consultants are asked to refer to Conservation Halton's approximate regulation limit mapping that has been provided to the Region via our data sharing agreement.

Staff also recommend pre-consultation with Conservation Halton with respect to detailed study components and requirements.

We trust the above is of assistance. If you require additional information, please contact the undersigned at extension 266.

Yours truly,

Jennifer Lawrence, MCIP, RPP
Manager, Environmental Planning

cc: Mr. Martin Bateson, Town of Milton, email
Ms Barb Koopmans and Ms Bronwyn Parker, Town of Milton, email
Mr. Brian Hudson, Region of Halton, email
Ms Karyn Poad, Region of Halton, email
Ms Melissa Green-Battison, Region of Halton, email
Ms Aurora McAllister, MNR- Aurora, email

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Appendix D – Response to Conservation Halton Comments (October 25, 2012) – Fluvial Geomorphology Study.

Comment 1

(Page 6)	Table 2 – It is suggested that bankfull channel measurements be collected at one pool, one riffle and one run feature both upstream and downstream of each road crossing structure. A conservative approach would be to size the crossing structure based on the largest bankfull measurement taken at each respective crossing.
Response:	As a bare minimum, it is agreed that such an approach could be considered appropriate for alluvial shear-dominated channels such as the Main and East Branch of Sixteen Mile Creek within the study area. However, for all the smaller channels, which are ephemeral and vegetation-dominated swales (or ditches), the morphological concept of bankfull width is a less appropriate metric of geomorphological hazard (although admittedly its application is still the most practical). Therefore, the average bankfull width is considered a more reasonable estimate of geomorphological form (as opposed the largest bankfull measurement), and thus the average has been used in the 2 times bankfull calculations to satisfy Conservation Halton's ecological criteria. Also see responses to Comments 3 and 7 below.

Comment 2

(Page 6)	The table notes the bankfull width for each crossing, and the photos in Appendix A appear to indicate site investigations spanned several days and different hydrologic conditions. Please provide a brief description on the timing of the field visits, and detail when the Top of Bank Width was defined, with respect to flow conditions.
Response:	Photos in Appendix A for Crossings 1 – 11 and 15 were taken on May 18, 2011 during high flow conditions. The timing and flow-conditions for detailed field surveys, including Top of Bank Widths, are outlined below: Crossing 1 – first survey May 24, 2011 (low-flow), second survey Aug-Nov, 2011 (low-flows) Crossing 2 – first survey May 24, 2011 (low-flow), second survey Aug-Nov, 2011 (low-flows) Crossing 3 – surveyed May 24, 2011 (low-flow) Crossing 4 – first survey May 24, 2011 (low-flow), second survey Aug-Nov, 2011 (low-flows) Crossing 5 – first survey May 18, 2011 (high-flow), second survey Aug-Nov, 2011 (low-flows) Crossing 5a – surveyed May 18, 2011 (high-flow) Crossing 6 – first survey May 18, 2011 (high-flow), second survey Aug-Nov, 2011 (low-flows) Crossing 7 – first survey June 20, 2011 (low-flow), second survey Aug-Nov, 2011 (low-flows) Crossing 8 – surveyed May 16, 2011 (low flow, but rainy) Crossing 9 – no access, visual road side survey May 18, 2011 (high-flow) Crossing 10 – no access, visual road side survey May 18, 2011 (high-flow) Crossing 11 – first survey June 20, 2011 (low-flow), second survey Aug-Nov, 2011 (low-flows) Crossing 12 – first survey May 24, 2011 (low-flow), second survey Aug-Nov, 2011 (low-flows) Crossing 13 – visual road side survey May 18, 2011 (high-flow) Crossing 14 – first survey May 24, 2011 (low-flow), second survey Aug-Nov, 2011 (low-flows) Crossing 15 – first survey June 20, 2011 (low-flow), second survey Aug-Nov, 2011 (low-flows) Crossing 16 – first survey June 20, 2011 (low-flow), second survey Aug-Nov, 2011 (low-flows) Crossing 17 – first survey June 20, 2011 (low-flow), second survey Aug-Nov, 2011 (low-flows) Crossing 18 – first survey June 20, 2011 (low-flow), second survey Aug-Nov, 2011 (low-flows)

Comment 3

(Page 6)	For Crossings 14, 17, and 18 the proposed culvert sizes will not be sufficient to contain the average bankfull width documented in Table 2 of the Fluvial Geomorphology Report. Geomorphic input on the appropriateness of these culvert sizes, relative to maintaining natural channel function and the erosion risk to the structure is required. See additional comments below regarding the draft Conceptual Fisheries Compensation Plan requirements for watercourse crossings in the Boyne Secondary Plan Area.
Response:	Culvert widths have been reassessed to satisfy Conservation Halton's requirement for minimum spans of 2 times the bankfull width to satisfy ecological objectives. The geomorphic assessment includes an updated stability analysis provided in the Fluvial Geomorphology report. In terms of geomorphic input, a strict notion that natural channel functions can be completely maintained in culverts on vegetation-dominated channels is unrealistic, but it is agreed that 2 times bankfull width is more than sufficient to minimize local interruptions in geomorphic processes and mitigate reach scale impacts of the crossings. Also see responses to Comments 5 and 7 below for further response.

Appendix D – Response to Conservation Halton Comments (October 25, 2012) – Fluvial Geomorphology Study.

Comment 4

(Page 6)	Table 4 - Staff note an error in Table 4 with respect to Crossing 16. Please revise.
Response:	Table 4 has been revised within the updated Fluvial Geomorphology Report.

Comment 5

(Page 6)	Table 6 indicates that the proposed conditions for 9 of the 19 culverts analyzed may have limited stability during some storm events, as the proposed velocity exceeds the estimated permissible velocity. Staff are particularly concerned with respect to Crossings 8, 10 (under option 5B), and 14, as these exceed the permissible velocities on a more frequent basis. Please provide additional discussion as to the impacts and mitigation measures associated with the velocity increases and identify appropriate commitments to be addressed through the detailed design. Is it anticipated that larger culvert sizes will be required for all eight crossings listed in Table 6? Will permissible velocity estimates be refined? At this stage, staff need confirmation that at a conceptual level crossings have been sized to allow maintenance of the natural channel process.
Response:	Based on increased culvert sizes in the updated Hydraulic and Fluvial Geomorphology reports, improved hydraulic conditions in terms of velocity and shear stress have now been demonstrated in the updated stability analysis for all crossings at nearly all flood levels. The few minor increases remaining in the hydraulic modeling results are considered to be below permissible levels for risks of local erosion (i.e., outlet velocities) and for risks of reach degradation (i.e., average shear stress). At the conceptual level of the Environmental EA study, the updated stability analysis demonstrates that the proposed culverts are not expected to increase risks of channel instability. As per Comment 3 above, the recommend structures are not expected to significantly impact geomorphic processes in the adjacent stream reaches, and are typically much better than existing conditions, but absolute maintenance of natural channel processes through culverts in vegetation-dominated watercourses is unrealistic. As per recommendations in Section 6.0 of the updated Fluvial Geomorphology report, its agreed that natural substrates should be used in open bottom culverts (as per recommendations of the draft Conceptual Fisheries Compensation Plan (CFCP) for the Boyne Survey), and should any hydraulic concerns be identified during detailed design they can be mitigated based on round stone sizing within the culverts (Also see response to Comment 7 below). No bed and minimal bank works are expected for the Main and East Branches of Sixteen Mile Creek associated with new (wider span) bridge construction at Crossings 7 and 15, and it is expected that existing channel processes will be maintained under proposed conditions at these two crossings.

Comment 6

(Page 7)	For all intermittent watercourses within the study area, it is preferred that watercourses be realigned if necessary to facilitate the entry of the watercourse at a perpendicular angle to Britannia Road. This is suggested to reduce the length of the culverts underneath Britannia Road as much as possible. Staff recognize that this will require significant coordination between the Region, Town, Conservation Halton and the landowners north and south of Britannia Road. The landowners in the Boyne Secondary Plan Area are proposing on-line Regional Storm controls. This could have a significant impact on the crossing designs and will need to be discussed in detail.
Response:	Details for recommended culvert alignments have been provided in the updated Fluvial Geomorphology report in Section 5.0 and Appendix C. It is expected that minor offsets in the location of the culvert inlets associated with oblique alignments or slightly relocated culverts could easily be accommodated by development restoration of stream corridors, as well as the location of any proposed online Regional Storm controls.

Appendix D – Response to Conservation Halton Comments (October 25, 2012) – Fluvial Geomorphology Study.

Comment 7

(Page 9)	As noted in previous meetings, there are a number of background documents that have been prepared by AMEC on behalf of the Town of Milton for the Boyne Survey. Although none of the documents have been endorsed by Conservation Halton yet, they contain important direction for works within the Secondary Plan Area, including watercourse crossings. With respect to watercourse crossing width requirements, Section 4.3 of the draft Conceptual Fisheries Compensation Plan for the Boyne Survey, prepared by AMEC, dated March 2011 provides detailed requirements that should be incorporated into any watercourse crossing. A portion of Section 4.3 is outlined below however, we recommend that a complete review of the draft CFCP and FSEMS be undertaken to ensure consistency… In addition, Table 4.8 in the draft CFCP identifies estimated hydraulic structures within the Boyne Survey. Section 4.3.1 of the draft CFCP also notes the following: *Each of the road crossings should be designed and constructed to provide the following:* *(a) Natural substrate through open footing design or through the use of an embedded culvert invert to a depth of 0.5m preferred (minimum 0.3m);* *(b) Low flow channel through crossing (this may involve staggering the depth of culvert inverts i.e. multiple culvert crossings to promote low flow through a single culvert.);* *(c) Minimum span opening recommended to be approximately twice the proposed bankfull width in order to maintain natural channel form.*
(Page 10)	***Detailed Design -*** At detailed design staff will require geomorphic input on the culvert sizing and design and channel realignment for each regulated watercourse. We also request that a commitment be made to the incorporation of single span open bottom crossings spanning 2 times the bankfull channel width, with the provision for wildlife passage, as per the draft Conceptual Fisheries Compensation Plan.
Response:	As noted in Comment 3 above, the culvert spans have all been reassessed for the hydraulic and stability analyses to meet the requirement of 2 times bankfull width as per Conservation Halton and the draft Conceptual Fisheries Compensation Plan (CFCP) for the Boyne Survey. Recommendations have also been made in the Fluvial Geomorphology report to reflect the use natural (round stone) substrate through open bottom culverts (Also see response to Comment 5 above). For all small ephemeral watercourses (i.e., with exception to Crossings 7 and 15), there are typically no native sources of coarse gravel and cobble to replace with the open bottom culverts and therefore some mixture of imported natural round stone and native fine material would be required to maintain stable beds and meet engineering requirements.