APPENDIX E

STORMWATER MANAGEMENT & FLUVIAL GEOMORPHOLOGY ASSESSMENTS

UEM PROJECT NO.: 14-508
DATE: MAY 2016

PREPARED FOR:

HALTON REGION

CONTACT AND LOCATION:
Alicia Jakaitis, Acting Senior Transportation Planner
Transportation Services
1151 Bronte Road
Oakville, Ontario
L6M 3L1

NINTH LINE TRANSPORTATION CORRIDOR IMPROVEMENTS
STORMWATER MANAGEMENT REPORT

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1.0 INTRODUCTION

The Ninth Line Transportation Corridor (Ninth Line) is an important corridor connecting Georgetown to the north, with Milton, Oakville, Mississauga and Highways 401/407/QEW to the south. The study area includes Ninth Line from Highway 407 as the south limit to 10 Side Road as a north limit, as well as a section of Steeles Avenue, a length of approximately 7.2 kilometers. The boundaries of the study area are shown in **Figure 1-1**.

Within the project limits, Ninth Line intersects with three roadways – 10 Side Road, 5 Side Road, and Steeles Avenue (as shown in **Figure 1-1**). In addition, residential driveways and agricultural equipment access routes connect to Ninth Line on both sides throughout the corridor. Ninth Line, within the study area, is designated as part of the Regional Road Network and is functionally classified as a Major Arterial in the Regional Official Plan and also recognized in the Town of Halton Hills Official Plan (2008).

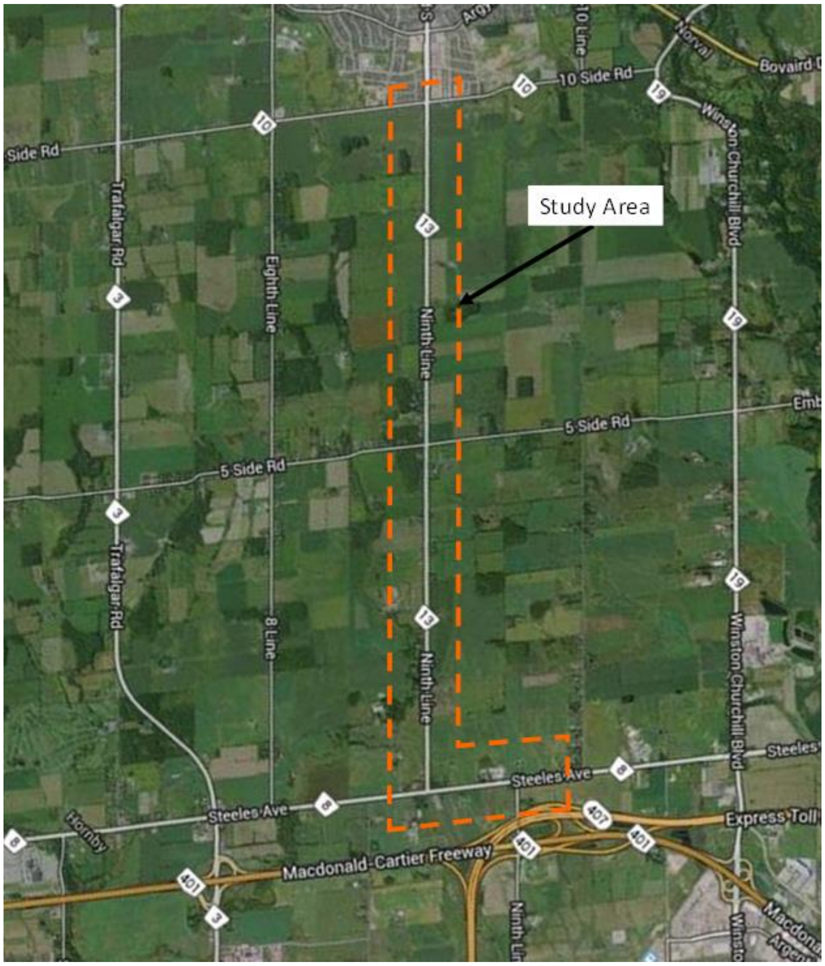


Figure 1-1 – Site Location

The purpose of this report is to provide an initial assessment of existing and proposed drainage conditions and stormwater management options.

2.0 EXISTING CONDITIONS

The study area consists of gently rolling hills with a higher elevation at the northern most limit of the study area. The study area is located within the East Branch catchment of Sixteen Mile . The surrounding landscape is generally characterized by large open fields interspersed with small forests and wooded fencerows and pockets of residential development. In the winter months, snow fences are constructed along sections of the Ninth Line Corridor that experience snow drifts in the presence of high winds.

2.1 LAND USE

The majority of the study area along Ninth Line from 10 Side Road to Steeles Avenue is rural. The northernmost section located within the Georgetown Urban Area boundary is designated as medium-density and low-density residential areas. The southernmost section of the study area is designated for ‘prestige industrial’ uses and an employment area. There is limited development planned within the study area to the year 2031.

2.2 WATER RESOURCES, TOPOGRAPHY, AND DRAINAGE

The study area is located within the East Branch catchment of the Sixteen Mile Creek system. Drainage for the Ninth Line road right-of-way is primarily via roadside ditches along both sides of the road. But drainage channels originating up-gradient of the road corridor enter the roadside drainage network and traverse the corridor through a series of culvert crossings under Ninth Line. Of these crossings, there is one major crossing of a small headwater tributary that traverses Ninth Line in the lower portion of the study area. This headwater tributary presents a flooding and erosion hazard as defined by the Conservation Authorities Act.

To investigate up-gradient drainage that traverses the study corridor, digital terrain data and local drainage channel locations were obtained from the Region. These data were supplemented by drainage catchment delineation and stream lines provided by Conservation Halton for Sixteen Mile Creek. Based on this information, a surface model of the study area was completed and the drainage patterns within this area examined. These results are shown in **Appendix A** as Drainage Area Plan Figures 1 through 3.

The primary tributary of interest flows perpendicular to Ninth Line with a bend north approximately 200 metres upstream of the road. The channel is relatively small and shallow. A preliminary fluvial geomorphic assessment for this channel is provided in Section 4.1 of this report. A photograph of the culvert is provided in **Figure 2-1**.

Figure 2-1 – Main Crossing Culvert

There is an additional major crossing (Discharge Area No. 5) at the east end of the study area, but this crossing is part of the current Steeles Avenue reconstruction and is therefore not assessed in this SWM report.

There are four additional corrugated steel pipe (CSP) culvert crossings that convey drainage from the eastern roadside ditches and rural lands to the west of the road as identified in Appendix A and listed in **Table 1**. These four culverts outlet into separate channels that continue westward to the East Branch of Sixteen Mile Creek. These culverts range from 450 mm to 1125mm. These culverts are below the 2,000 mm diameter used by the Region as the threshold to track the culvert condition, therefore there is no historical data for these culverts. Visual observations by the team indicated these culverts were in generally good condition with some minor deformations, corrosion, and silting of the pipes. There are additional driveway culverts in the study area that connect the parallel roadside ditches through existing driveways and other culverts that provide a hydraulic connection between the roadside ditches on the eastern and western sides of Ninth Line.

Table 1 – Ninth Line Culvert Crossings that Discharge out of Study Area

Discharge Point	Station	Dimension	Catchment Area (ha)
1	1+238	700 mm dia CSP	109.
	1+247	900 mm dia CSP	
2	3+056	450 mm dia CSP	36.
3	3+498	1125 mm dia CSP	37.
4 (main crossing)	5+180	3000 mm wide Concrete Box	196.
5 (part of Steeles Ave re-construction)	6+139	1900 mm wide Concrete Box	53.

The total catchment area up-gradient of the five discharge points is 432.0 ha. There is an additional 25.8 ha of drainage areas west of Ninth Line that is collected by the existing Ninth Line roadside ditches.

2.3 RAINFALL

Rainfall statistics for the site were obtained from the Town of Halton Hills “Development Manual” and are provided in **Appendix B**. Hurricane Hazel is recognized as the Regional Storm for this location and intensities for the final 12 hours of the storm (212mm total depth) are provided in Appendix B.

2.4 SOILS AND PHYSIOGRAPHY

The Sixteen Mile Creek watershed consists of approximately 42,000 ha with headwaters originating above the Niagara Escarpment, flowing through the Peel Plain into Lake Ontario. The Main and Middle branches of Sixteen Mile Creek originate in the Bedrock Plain west of the Escarpment. Groundwater seepage from the steep escarpment slopes provides base flow to the lower reaches of the Creek. The East and Middle branches of the Creek merge just south of Hornby. Below the Escarpment, Sixteen Mile

Creek flows onto the Peel Plain where the clay soils have much lower infiltration rates resulting in higher surface runoff and limited groundwater recharge of the Creek (GTA West Corridor, 2010).

The physiography of the eastern branch of the Sixteen Mile Creek Watershed is dominated by the Peel Plain, an expansive area characterized by level to undulating topography with a gradual slope towards Lake Ontario. The unique Halton till soils of the area provide for agricultural significance (GTA West Corridor, 2010). It has also been noted that the eastern portion of the watershed is characterized by an area of clay and clay-loam soils with low topographic relief and imperfect drainage (Dunn, 2007).

A soil map of the drainage area using imagery from the published Ontario Soils Survey is provided in **Appendix C**. The predominant soil is Chinguacousy type (loam and clay loam) with pockets of Dumfries, Jeddo, and Oneida. Based on the OMAFRA Drainage Guide for Ontario (excerpt provided in **Appendix C**), these soils are predominantly Hydrologic Soil Group Type C.

3.0 PROPOSED ROADWAY IMPROVEMENTS

In consultation with stakeholders and technical agencies, the Project Team selected “a combination of widening about the centerline, to the east and to the west” as the preferred alternative for widening Ninth Line from two to four lanes. The preferred alternative, in conjunction with the incorporation of modified cross-sections, is the only alternative that offers the flexibility required to mitigate the negative effects that widening poses to the natural and social environment.

The impact of the proposed roadway improvements to water resources and drainage features includes:

1. Collection and Conveyance (Section 4)
    a. Main Road Crossing (at Station 5+180)
    b. Minor Crossings at existing Discharge Points (at Stations 1+238, 1+247, 3+056 and 3+498)
    c. Other Minor Road Crossings Culverts (connect ditches from one side of the road to other)
    d. Roadside Ditches and Driveway Culverts
2. Impact on Flood Lines (Section 4) – based on discussion with Conservation Halton, this included a preliminary assessment of the impact on flood lines of the proposed road works and culvert replacement at Station 5+180 (Discharge Point #4). The culvert replacement will be of same type as currently in place (open bottom) which is consistent with Halton practice and Conservation Halton preferences.
3. Stormwater Management (Section 5)

4.0 CULVERT CROSSING REVIEW

Existing and proposed drainage areas are shown in **Appendix A**, listed in **Tables 2**, and summarized in **Table 3** for the existing and proposed crossing culverts and outlets. The road widening will increase the impervious Ninth Line road surface area from 2.2% of the study area to 4.5% of the 457ha study drainage area.

All replacement culverts will be designed to conform to the MTO Drainage Management Manual (1997) and Highway Drainage Design Standards (2008). No development is planned within the channel catchment except for the proposed road widening.

Table 2 – Drainage Catchments

Discharge Point	Catchment	Area (ha)	Notes
0 (new proposed outlet)	N0a	22.3	In existing case, discharges at #1
	S0a	2.0	In existing case, discharges at #1
1	N1a	86.7	
	S1a	8.4	
2 (proposed major flows redirected to Outlet 3)	N2a	28.4	In proposed case, major discharges re-routed to #3
	N2b	7.9	In proposed case, major discharges re-routed to #3
	S2a	1.8	In proposed case, major discharges re-routed to #3
3	N3a	33.7	
	N3b	3.4	
	S3a	1.2	
4 (main crossing)	N4a	38.8	
	N4b	145.4	
	N4c	7.8	
	N4d	4.4	
	S4a	6.0	
5 (part of Steeles Ave reconstruction)	N5a	45.5	
	N5b	7.2	
	S5a	6.4	
TOTAL		457.3	

***Note**: Catchments starting with "N" are on the northeastern side of Ninth Line. Those starting with "S" are on the southwestern side.*

Table 3 – Summary of Existing and Proposed Catchments

Discharge Point	**Station**		**Existing Area (ha)**	**Proposed Area (ha)**
0	0+408	To culvert To outlet	na na	22.3 24.3
1	1+238	To culvert To outlet	109.0 119.4	86.7 95.1
2*	3+056	To culvert To outlet	36.3 38.1	na na
3	3+498	To culvert To outlet	37.1 38.3	73.4 76.4
4 (main crossing)	5+180	To culvert To outlet	196.4 202.4	196.4 202.4

*Note: * Minor drainage flows will continue to discharge through Discharge Point #2, but an alternative flow route will re-direct some major flows (from greater than the 5-yr storm) from Discharge Point #2 to Discharge Point #3. "Proposed Area" shown here is for the major flow re-direct. For Minor Flows, the Proposed Area will be the same as the Existing Area for both discharge points.*

4.1 MAIN CULVERT CROSSING

The main culvert crossing (Discharge Point 4 at 5+180) is a 3m wide open bottom box culvert. An assessment completed for this report includes:

- Hydrology and Hydraulics – to determine existing and expected peak flow rates using Visual HYMO, and expected flood line elevations near the crossing using HEC-RAS
- Fluvial Geomorphic Assessment – to establish bank full width

4.1.1 HYDROLOGY AND HYDRAULIC ASSESSMENT

A preliminary assessment of peak flow rates for the main culvert crossing was completed using Visual HYMO. Inputs and model outputs for this assessment are provided in **Appendix D**. A summary of inputs includes:

- the catchment for the discharge point was divided into 4 sub-catchments;
- based on Town of Halton Hills rainfall data, a 12-hr SCS Type 2 mass curve was developed with a 15 minute time interval;
- Time of Concentration for each catchment was calculated using the Airport Method; and
- based on the predominant soil type, SCS Curve Number (CN) was set at 88 for all design storms except the Regional Storm where an assumed higher antecedent moisture condition resulted in a CN of 95.

The peak flows for each design storm are shown in **Table 4**.

Table 4 – Peak Flow Rates at Main Crossing

Return Period	Peak Flow (cms)
2-yr	3.8
5-yr	6.7
10-yr	8.7
25-yr	11.3
50-yr	13.3
100-yr	15.2
Regional	21.5

These flow rates are likely conservative (high) based on modelling inputs and assumptions.

These flow rates were then applied to the HEC-RAS model of the drainage system provided by Conservation Halton. Detailed results are provided in **Appendix D**. A summary of results is provided in **Table 5** by examining the flood plain elevation at the modelled cross section nearest to the road. This assessment was completed for the current culvert cross section, plus at two and three times bankfull width. Increasing the height of the culvert opening from 0.7m to 1.5m was also examined.

In **Table 5**, the road surface is threatened during 25-year return period storms with a new 3.0m wide by 0.7m deep culvert (but longer to traverse new wider road). However, when the culvert opening is increased to account for two or three times bankfull width, the floodplain elevations for all design storms are well below the proposed road surface elevation at the crossing.

Table 5 – Flood Plain Elevation at Road Crossing

		Proposed 3m x 0.7m Box Culvert	Proposed 10m x 0.7m Box Culvert	Proposed 10m x 1.5m Box Culvert	Proposed 15m x 0.7m Box Culvert	Proposed 15m x 1.5m Box Culvert
2 Yr		213.32	212.77	212.77	212.65	212.65
5 Yr		213.83	212.96	212.96	212.78	212.78
10 Yr		214.37	213.07	213.07	212.86	212.86
25 Yr		**214.73***	213.21	213.21	212.96	212.96
50 Yr		**214.78***	213.32	213.31	213.03	213.03
100 Yr		**214.80***	213.40	213.40	213.09	213.09
Regional		**214.92***	213.75	213.68	213.29	213.29
Culvert	UP Invert	212.56	212.56	212.36	212.56	212.36
	DN Invert	212.05	212.05	211.80	212.05	211.80
	UP Obvert	213.26	213.26	213.86	213.26	213.86
Road Crest Height		214.68	214.68	214.68	214.68	214.68
Culvert Open Channel Capacity (cms)		3.5 < 2-yr storm	13.9 > 50-yr storm	47.6 > Regional Storm	21.4 > 100-yr storm	75.3 > Regional Storm

Note: * Flood line elevation is above road crest

The bottom row of **Table 5** also shows the open channel capacity of each culvert option calculated independently (see **Appendix D** for details). When compared to the peak flow rates in **Table 4**, results show that a new culvert with a 10m width and 0.7m depth can pass the 50 year peak flow without restriction, which meets the required 50 year storm (MTO, Rural Arterial, .6m span). Larger culverts (wider and/or deeper) can pass the Regional Storm peak flow under open channel conditions. Conservation Halton has requested that the Region consider an ultimate culvert design that keeps Ninth Line road surface flood free under Regional Storm conditions.

4.1.2 FLUVIAL GEOMORPHIC ASSESSMENT

A site visit was made by UEM's Fluvial Geomorphologist on 10 December 2015. During this field survey, a Rapid Geomorphic Assessment (RGA) was undertaken as well as the survey of two cross sections upstream of the culvert crossing on Ninth Line. The RGA was undertaken to determine the current geomorphic status of the sections. Bankfull geometry estimates cannot be made without knowing the stability status of the channel in question. Sections were measured to characterize the existing geometry of the stream bed.

The RGA used for this project is a UEM standard assessment adapted from the Ontario Ministry of Environment's (MOE) Stormwater Management and Planning Manual, Appendix C, Rapid Geomorphic Assessment, 2003 (Ontario Ministry of Environment, 2003), the State of Maine's Rapid Geomorphic Assessment, Appendix J-3, 2007 (State of Maine, 2007), and the NCHRP's Report 25-25 (8), Developing Performance Data Collection Protocol for Stream Restoration, 2006 (National Cooperative Highway Research Program, 2006). Each of the study reaches was evaluated for specific evidence of:

- Aggradation,
- Degradation,
- Widening, and
- Plan Form Adjustment.

From this evaluation, an index score was derived. The index scores are indicative of general geomorphic stability: a score of less than 0.20 indicates a stable system (in-regime), a score of 0.21 to 0.40 indicates a stressed/transitional system, while a score of greater than 0.40 is indicative of an adjusting (instable) system.

The RGA survey was based upon a physical inspection of approximately 300 metres of channel (and stream valley) upstream of the culvert crossing on Ninth Line. The RGA observation sheet is presented in **Appendix E**.

It is apparent that the channel geomorphology upstream of the culvert has been impacted by human activities, insofar as the RGA score of 0.26 indicates that the stream is in a state of transition, from stability to instability. The primary driver for this transition to instability appears to be degradation (erosional loss and entrenchment) followed by plan form adjustment (meander loss and re-establishment). Agricultural interference in the form of channelization and ploughing to and through the channel and its valley complex seem to be the primary cause.

Because of the transitional nature of the stream system as it presently exists, it is important to note that bankfull geometry indicators should be used with caution.

The existing channel configuration can be used to estimate the magnitude of the bank-forming flow event and thus the bankfull stream width. The bank forming event is that stage and velocity of water in the channel that exhibits a recurrence between once a year and once every two years (1 to 2-year return flow frequency). In-situ conditions such as channel friction/roughness, channel morphology data such as bankfull width and depth and mean profile slope can be utilized to estimate the bankfull flow (capacity) of the channel as it is currently configured. These data can also be used to estimate the bankfull channel velocity that has given rise to the conditions observed in the channel during the geomorphic site assessment.

Only the reach immediately upstream of the culvert (to 60 metres upstream of the culvert inlet) presented evidence of a clearly defined bankfull depth and width. Beyond this thalweg distance, the stream bed and valley are too disturbed by long term ploughing to adequately discern the bankfull width/depth of the channel.

Two sections were surveyed. The first was within the disturbed channel, approximately 125 metres upstream of the culvert inlet. This channel section was surveyed to determine the severity of channel disturbance from agricultural activities. Figure 4-1, details the setting for this cross section survey.

Figure 4-1 – Channel Survey Section in Disturbed Area (approx. 125 m upstream of culvert inlet)

The measured cross-section for this location is depicted in Figure 4-2.

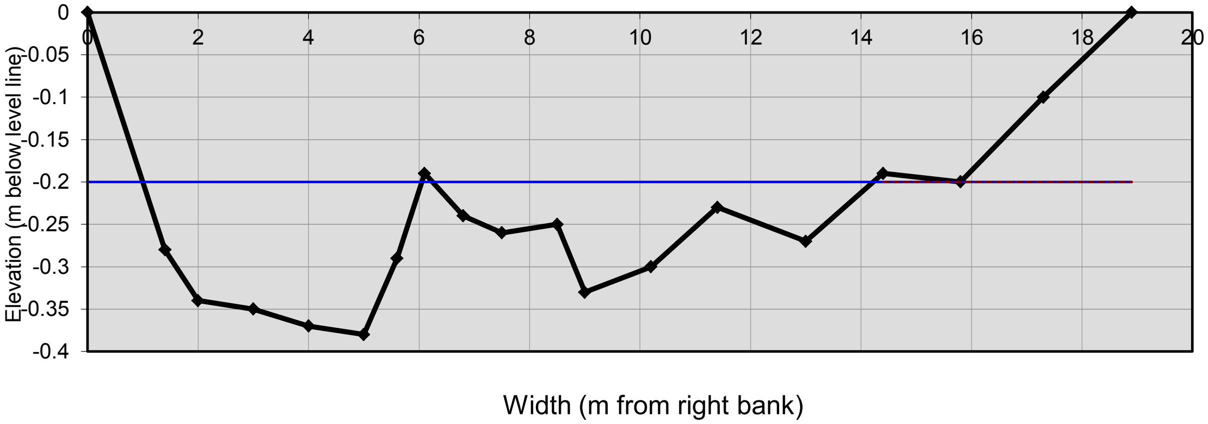


Figure 4-2 – Channel Cross-section in Disturbed Area (approx. 125 m upstream of culvert inlet)

The second section was located approximately 25 metres upstream of the culvert inlet, within the reach that exhibits a clearly defined (albeit entrenched) channel. Figure 4-3 details the location of this section.

Figure 4-3 – Channel Survey Section in Defined Channel Area (approx. 25 m upstream of culvert inlet)

The measured cross-section for this location is depicted in Figure 4-4.

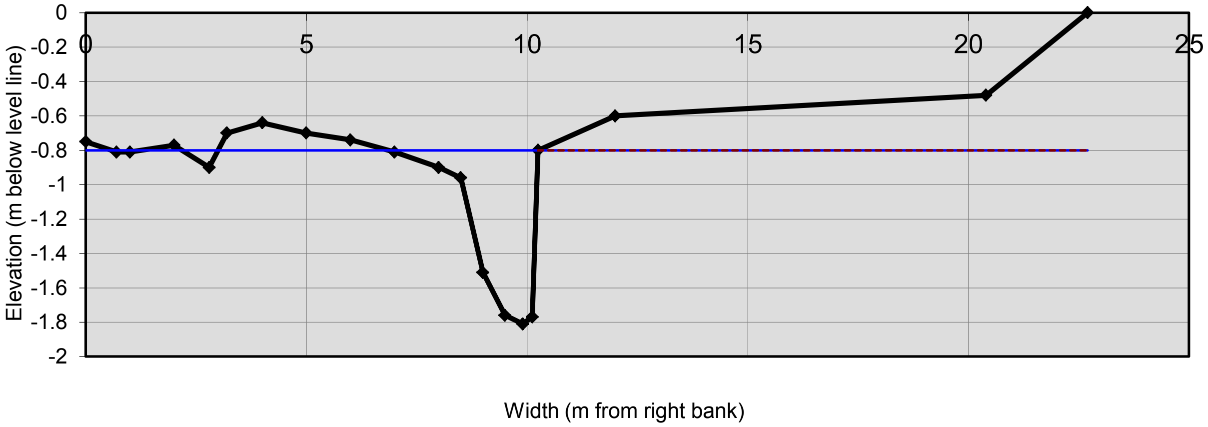


Figure 4-4 – Channel Cross-section in Defined Channel Area (approx. 25 m upstream of culvert inlet)

Given the defined cross section detailed in Figure 4-4 above, Table 6 details the stream morphology parameters observed in the upstream sub-reach during the geomorphic assessment.

Table 6 – Geomorphic Parameters for the Bankfull Flow Event (determined in-situ)

Geomorphic Component Measured In-Situ	**Value**
Bankfull Width (W_{BF})	4.9 m
Bankfull Depth (D_{BF})	1.0 m
Bankfull Wetted Perimeter (P_{BF})	6.1 m
Bankfull Hydraulic Radius (R_{BF})	0.5 m
Mean Thalweg Slope (S)	0.010 m/m = 1.0%
Manning's Friction Coeff. (n), from (Chow, 1959)	0.030 (clean, straight, full stage, no rifts or deep pools)

Manning's n, the friction co-efficient was estimated from the literature (Chow, 1959) since the bed was smooth clay with minimal alluvial material. From these geomorphic data, flow components can be estimated. Table 7 details the bankfull flow parameters calculated using the observations of Table 6.

Table 7 – Bankfull Flow Components (estimated using in-situ indicators)

Geomorphic Component Measured In-Situ	**Value**
Bankfull Velocity (V_{BF})	1.3 m/s
Bankfull Discharge (Q_{BF})	1.9 m^3/s
Froude Number (Fr)	0.83 (sub-critical)
Shear Stress at Bed (T_b) – aka Shield's Parameter	23.85 N/m^2
Threshold Particle Size (incipient motion via Shield's Equation)	25 mm

The observed entrenchment of the stream at the cross section 25 metres upstream of the culvert inlet is thus well explained by the predicted bed shear stress (Tb) of 23.85 N/m2.

Any works proposed for the existing culvert should seek to stabilize the channel upstream, to avoid erosion of the stream at the culvert as well as damage to the culvert itself. An inlet contraction pool should be designed using bio-engineering elements that will bring about the required stability.

In support of detailed design for the entire Ninth Line study corridor, the following additional fluvial geomorphic assessments are recommended:

- Meander Belt and Width Change Assessment of existing channel based on historical imagery.
- Rapid Geomorphic Assessment (RGA) of channel downstream of the existing main culvert crossing to convergence with tributary west of Ninth Line, to assess stability of downstream channel. Conservation Halton typically requires that "new or replacement structures will facilitate appropriate bankfull flows, water depth, water velocities and tractive forces." These parameters should be the same through the crossing as in upstream and downstream natural areas.
- Rapid Geomorphic Assessment (RGA) of minor channels associated with the two minor crossing that will be retained in the final design (at Stn. 1+238 and Stn. 3+498).

A bankfull flow competence analysis of existing channel based on a Wolman count is not recommended at this location.

Additionally, a fluvial geomorphologist should provide advice and design guidance on:

- proposed main culvert width in relation to bankfull width and potential meander melt migration;
- channel base and low flow channel configuration through proposed new culvert;
- proposed bank stabilization design upstream and downstream of proposed main culvert;
- contraction pool design upstream of proposed main culvert; and
- sediment trap design at ditch and channel locations;
- channel stabilization downstream of proposed new culvert crossing at 0+408.

4.1.3 PROPOSED MODIFICATIONS

Recommendations for this main crossing include:

- Size – To meet Conservation Halton requirements, the proposed goal will be to achieve a "three times bankfull width" culvert opening of approximately 15m wide by 0.7m high. During detailed design, a full fluvial geomorphic assessment will be completed to look at the feasibility of using a smaller culvert opening along with "natural channel design" bank stabilization techniques upstream of the culvert to stabilize the upstream channel to reduce the risk of meander belt migration. The culvert should also be large enough to meet MTO criteria for passing at least a 50-year flow. Conservation Halton has requested that the Region consider an ultimate culvert design that keeps Ninth Line road surface flood free under Regional Storm conditions.
- Length – Conservation Halton has requested that all efforts be made during detailed design to minimize the length of the culvert.
- Type – Open footed concrete culvert with natural channel bottom and a stabilized low flow channel through the culvert passage. Given the significant width for three times bankfull, alternative open footing techniques (e.g., a bridge) may need to be considered.
- Inlet contraction pool – and bioengineered elements to stabilize the crossing site (i.e., stop the entrenching). Bioengineering techniques that should be considered include hardening the banks with crib-walls and or layered vegetation (matts).
- Alignment – will be as close as possible to perpendicular to the road, but will account for existing up-gradient and down-gradient meander which may require a modified alignment. Downstream bank stabilization using natural channel design techniques will be considered, in addition to similar upstream treatment, if needed to ensure stability of the downstream channel banks based on the assessment of the fluvial geomorphologist.
- Low flow channel – within the open bottom, a low flow channel will be established to convey baseflow.
- Wet swales or sediment traps – to address sediment issues and channel erosion where roadside conveyance and the channel converge. Wet swales or sediment traps in the ditches before discharge locations into the main channel are recommended. MOECC (2003) ***Stormwater Management Planning and Design Manual*** states that "Wet swales combine elements of dry swale systems and wetland systems. Wet swales are typically wider than dry swales (e.g., 4 m - 6 m) and the check dams are used to create shallow impoundments in which wetland vegetation is planted or allowed to colonize. Because of their width, wet swales are not generally implemented along the front of residential properties, but rather are included where overland flow routes use linear open space areas."

The Region is committed to arranging a full geomorphological assessment during the detailed design phase of the project to help address some of the above stability and sediment loading issues.

4.2 CULVERT CROSSINGS AT OTHER DISCHARGE POINTS

Due to road widening, all minor culvert crossings will have to be replaced with longer culverts. The replacement culverts will also be designed to conform to the MTO Drainage Management Manual (1997), and Highway Drainage Design Standards (2008) and the MTO Gravity Pipe Design Guidelines: Circular Culverts and Storm Sewers (Revised, April 2014). Based on the MTO Drainage Manual, for crossings of a rural arterial road with a span less than 6m, the culverts should at a minimum be designed to convey peak flow from a 25 year storm.

The current preliminary corridor configuration indicates that a new discharge point may be required at Station 0+408 (Discharge Point 0) to address a new low point in the proposed roadside ditch system. This would reduce the runoff at Discharge Point 1 (Station 1+240) but introduce new flows into an existing channel southwest of the road at this 0+408. If this new discharge point is retained through final design stage, then additional information will need to be collected on the receiving channel, impact on drainage divides evaluated, and stormwater management and culvert design implications assessed.

Preliminary road design also indicates that a secondary flow route is required for major flows (greater than the five year storm) from crossing culvert at 3+056 (Discharge 2) to the culvert at 3+498 (Discharge 3). An urban cross-section is required in this stretch of road to accommodate the presence of private homes on both sides of Ninth Line and minimize impacts on the woodlot and wetlands in the northwest quadrant. Due to elevation constraints, it is proposed to replace the existing 450mm diameter CSP culvert at 3+056 with a 450 mm diameter concrete culvert to handle proposed minor flows. A secondary culvert will cross 5 Side Road to divert some major flows to from Discharge 2 to Discharge 3. The flow route from both these existing discharge points skirt a wetland south of the intersection of 5 Side Road and Ninth Line and form a confluence south of the wetland as shown in **Figure 4-5**. As part of detailed design, these existing channels and ditches down to the existing confluence will be investigated to ensure changing flow regimes (during major flow events) will not have an adverse impact, or that channel modifications as needed to handle increased flows are designed into the proposed works.

Table 8 provides a summary of preliminary recommendations for culvert replacements that account for reduced culvert slopes due to longer spans, and meet the MTO conveyance criteria. This preliminary assessment was based on the Rational Method and details are provided in **Appendix F**.

The results in **Table 8** are based on a conservative open channel calculation of peak flow capacity of the proposed culverts. During detailed design, a more detailed assessment should be completed to see if smaller culverts under surcharged conditions can convey the peak flows and meet MTO requirements in detail. At locations where large or twin culverts are needed, Conservation Halton has requested consideration be given to a box culvert to provide more effective flow and channel characteristics for the watercourse feature.

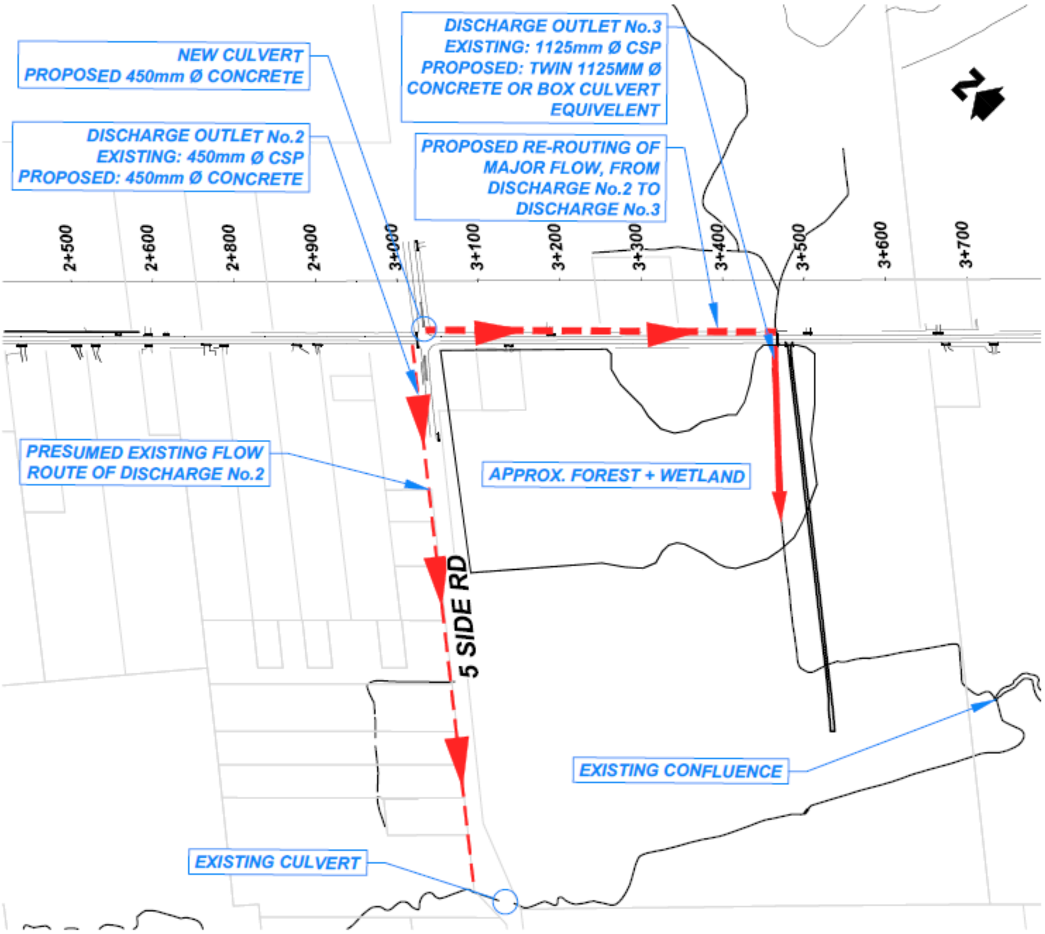


Figure 4-5 –Downstream Flow Routes from of Culverts at 3+056 and 3+498

Table 8 – Ninth Line Minor Culvert Crossings that Discharge out of Study Area

Discharge Point	Station	Existing Dimension	Proposed Dimension
0	0+408	none	900mm dia concrete
1	1+238	700 mm dia CSP	Twin 1050 mm dia concrete – or box culvert with equivalent capacity
	1+247	900 mm dia CSP	
2	3+056	450 mm dia CSP	450 mm dia concrete
3	3+498	1125 mm dia CSP	Twin 1125 mm dia concrete – or box culvert with equivalent capacity

4.3 OTHER CULVERT CROSSINGS

There are at least two intermediate culvert crossings that are not located at existing discharge/outlet points. These crossings convey flow from the east side ditch to the west side ditch. These connections potentially help to balance out flows between the east and west side ditches as there is a significant disparity between catchment areas for lands east of the roadside (432 ha) and west of the roadside (26 ha), particularly at the northern end of the system tributary to Drainage Area No. 1 in Figure No. 1 in **Appendix A**.

During detailed design, consideration will be given to more sites for this type of intermediate crossings as part of overall collection system design. The locations of existing crossings at the northern end of the study area should be maintained with new culverts installed to maintain existing conveyance capacity.

4.4 ROADSIDE DITCHES AND CULVERTS

From a drainage perspective, there are three types of road cross sections and related roadside conveyance proposed for the rebuilt road as shown in **Appendix G**. These include:

- **Rural Section** – roadside trapezoidal shaped ditches with a 1m flat bottom and a 3:1 side slope closest to the road and a 2:1 side slope toward the surrounding land.
- **Semi-rural Section** – ditches on the one side of the road, with a storm sewer aligned along the other road boundary
- **Urban Section** – curb and catchbasins that discharge into a storm sewer aligned with the road centreline

The current preliminary includes trapezoidal-shaped ditches with a typical slope of 0.5% and some steeper sections as necessary.

The worst case scenario for roadside ditches is the northern end of the study area where significant farmland enters the roadside ditch. About two-thirds of the proposed N1a 89.7ha ha catchment area is tributary to specific ditch sections. Using two-thirds of the 25-yr peak flow used to determine the sizes of the culverts in Table 6 from Section 6.2 (details in **Appendix F**), results in a peak flow of 2.6 m^3/s in the ditch. In the proposed trapezoidal-shaped ditch, assuming a Manning's n of 0.040 and a slope of 0.5%, the depth of flow would be 0.8m with a velocity of 1.0 m/s. This suggests that a maximum ditch depth of 1m will generally be sufficient, with shallower depths suitable in other locations.

5.0 STORMWATER MANAGEMENT

As per MOE SWMP Manual and the 16 Mile Creek Watershed Plan:

- **Quality** requirements are Enhanced/Level 1 treatment (long-term average removal of 80% of suspended solids),
- **Quantity** requirements are post to pre development controls to the extent possible
- **Erosion control and detention storage** requirements are implemented to the extent possible

Stormwater quality and quantity control is proposed through a treatment train approach that includes maintenance and enhancement of the existing rural ditches where possible. A trapezoidal vegetated ditch is preferred over a V-shape ditch to increase water infiltration rates to offset the increased impermeable surface area posed by the road widening. A vegetated ditch with a shallow slope also improves stormwater runoff quality. Additional techniques to control quality are discussed later in this section so that a treatment train approach is used to ensure that water quality control objectives are achieved.

Shallow sloped, trapezoidal, vegetated ditches will be used along the road corridor in all “Rural” sections and will be the primary method of quality, quantity and erosion control. Typical slope of the proposed ditch is 0.5%, with a 3:1 side slope adjacent to the road and 2:1 side slope on the opposite side. A base width of 1.0 m is proposed.

Table 9 provides a preliminary estimate of existing and post-development peak flows based on Rational Method for the 100 year storm. Discharge Point 4 estimates are significantly lower than those computed using Visual HYMO presented earlier in this report. This is likely due to the preliminary and un-calibrated nature of the modelling. And due to the tendency of Rational Method to underestimate low frequency storms (like the 100-year storm) as the runoff coefficient is actually a function of rainfall intensity and will increase with rainfall volume and intensity of a storm. These preliminary estimates are only provided here to illustrate the relative impact of proposed road works and drainage configuration on peak flows at each discharge point.

Table 9 – Ninth Line Pre and Post Peak Flows for 100 Year Storm

Discharge Point (DP)	Peak Flow (cms)		Notes
	Existing	Post Development	
0	0.0	1.4	New proposed discharge point. Takes some of Existing DP #1 flows
1	5.9	4.9	Some of this flow is diverted to DP# 0
2	2.7	0.0	Assumes most of major flow (> 5-year storm) is re-directed to DP #3
3	2.5	5.1	Most of increase due to major flow (> 5-year storm) diverted from DP #2 to DP #3
4	7.7	7.8	A 1% increase in flow due to proposed road works

The primary changes in peak flow rates are due to changes in catchment areas for Discharge Points 0 thru 4. Discharge Point 0 is a new point and downstream channel will need to be designed to adequately convey the flow. Similarly, the peak major flow at Discharge Point 3 will increase as it will now take major flows from the culvert at Discharge Point 2. The confluence for these two outlets is approximately 200m south of the Discharge Point 3. This channel is straight and likely engineered and should be assessed to ensure it can handle the increased peak major flows until the confluence.

The increase in peak flow at Discharge Point 4 is a 1% increase in peak flow and is due only to expanded road works. The proposed trapezoidal channel should reduce this peak flow.

To help further improve water quality and quantity control, a treatment train approach that considers the following stormwater management options will be evaluated during final design in addition to the roadside trapezoidal ditches:

- **Wet swale** or **sediment traps** in all ditches prior to discharge into any of the main or minor discharge points. For the minor crossings, it may be possible to consolidate the sediment control within the channel instead of the roadside ditches. These devices also provide detention storage for high frequency rainfall events.

- Add strategic **check dams** to the trapezoidal ditches to provide additional detention storage for water quality control.
- All “Semi Rural” or “Urban” cross sections discharge into “Rural” trapezoidal ditches with the exception of the “Semi Rural” section that discharges into the downstream end of the major crossing at Discharge Point 4 (5+180). All other rural sections will therefore be controlled (quantity and quality) by the downstream trapezoidal ditching. To help control water quality from the “Semi Rural” at the major discharge at 5+180, two techniques are proposed:
    - Add a **sediment trap** or **wet swale** near the inlet of the proposed storm sewer to provide additional quality control on the flows entering the ditch, and
    - Use **oil grit separators** at the catchbasins immediately upstream of the storm sewer discharged to the main watercourse near 5+180.
- Consider using Low Impact Development (LID) techniques. Conservation Halton recommends that discussions between the designing Landscape Architect and Engineer take place at the onset of the detailed design process to refine LID options (e.g., tree pits, bio-retention areas within proposed landscape area within the project limits). Other techniques could include:
    - Porous granular buffer – between the paved shoulder and the multi-use path in the typical proposed rural cross section highlighted in **Figure 5-1**. This buffer width should be maximized and subsurface fill selected to promote infiltration. This will reduce peak flows for frequent rainfall events and provide an additional measure of water quality control.
    - Porous asphalt bicycle lane (**Figure 5-2**) – in the “Semi Rural” section that discharges to the main crossing at 5+180. It may be possible to extend the porous asphalt bike lanes through the Rural section as well depending on relative cost. Permeable asphalt is not recommended where sand is used for winter road treatment.

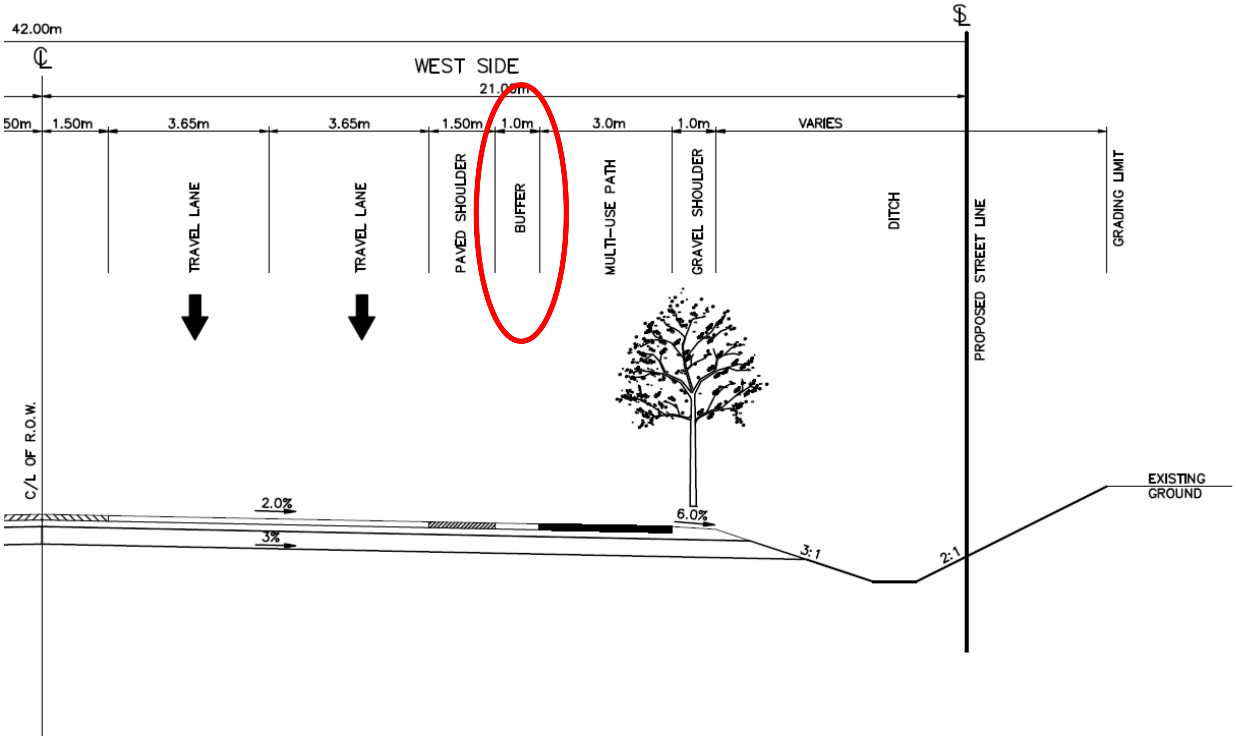


Figure 5-1 – Porous Buffer between Paved Shoulder and Multi-use Path in “Rural” Cross Section

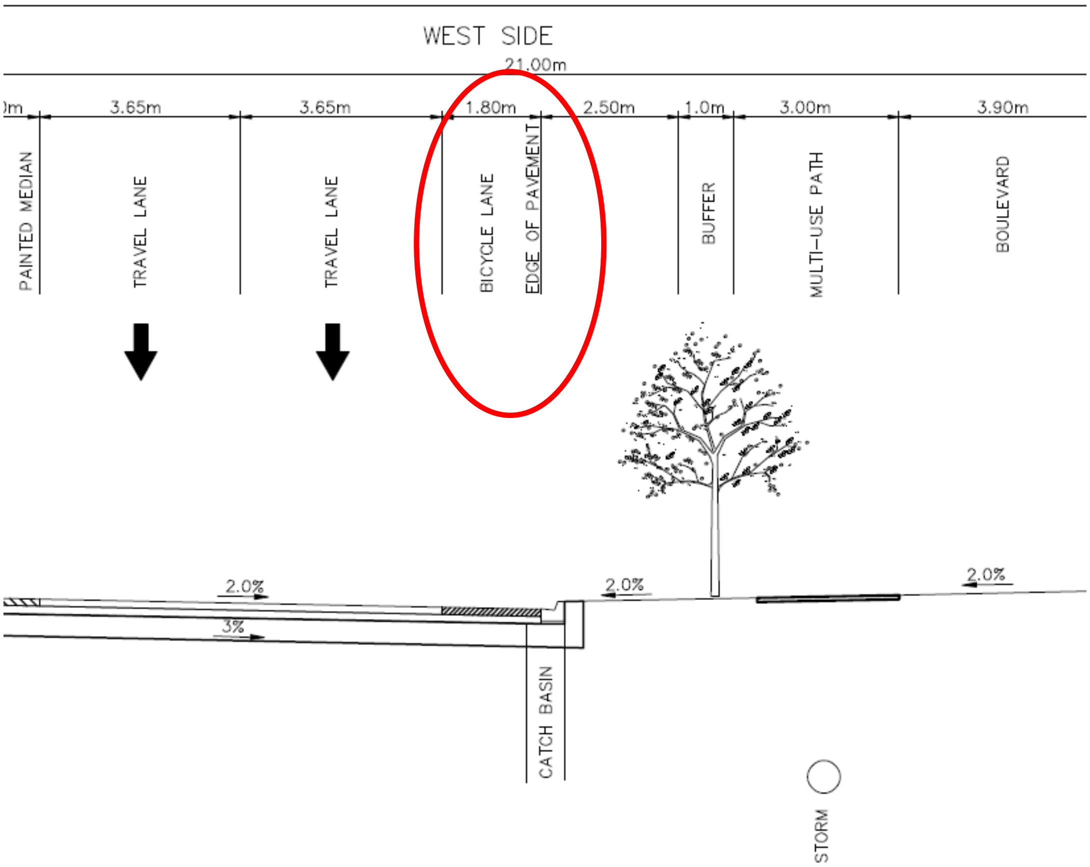


Figure 5-2 – Porous Asphalt Bicycle Lane in “Semi Rural” Cross Section near 5+180

Figure 5-3 – Example of Porous Asphalt Bicycle Lane
(from Credit Valley Conservation, Grey to Green Road Retrofits, 2014)

6.0 SEDIMENT AND EROSION CONTROL

For construction erosion and sediment control plans, the Region will retain a certified professional, either a qualified professional designated as a Certified Inspector of Sediment and Erosion Control (CISEC), Certified Professional in Erosion and Sediment Control (CPESC) or suitable equivalent to create and implement the plans. This should be undertaken at the tendering and construction phases of the project.

7.0 CONCLUSIONS

Based on this review of drainage and stormwater management:

- There is limited development anticipated in the study area to the year 2031. Therefore changes to the hydrological characteristics of the study area will be primarily due to road widening.
- There is currently one major channel crossing of Ninth Line through a 3m wide open bottom box culvert. This culvert will be replaced with a wider open bottom box culvert. Details of this proposed new culvert will be developed during final design based on a fluvial geomorphic assessment and natural channel design principles. An initial calculation based on a proposed span that is three times the bankfull width of the upstream creek indicates that this span could be up to 15m wide. During detailed design, additional fluvial geomorphic investigations will be undertaken and opportunities will be examined to reduce this span by enhancing channel stability through construction of a contraction pool and bioengineered bank hardening (e.g., crib walls and layered vegetation). Additional recommendations for this culvert include:
    - Size – The culvert should also be large enough to meet MTO criteria for passing at least a 50-year flow. Conservation Halton has requested that the Region consider an ultimate culvert design that keeps Ninth Line road surface flood free under Regional Storm conditions.
    - Length – Conservation Halton has requested that all efforts be made during detailed design to minimize the length of the culvert.
    - Type – Open footed concrete culvert with natural channel bottom. Given the significant width required to accommodate the three times bankfull requirement, alternative open footing techniques (e.g., a bridge) may need to be considered unless bank stabilization can provide relief from this width requirement.
    - Inlet contraction pool – and bioengineered elements to stabilize the crossing site (i.e., stop the entrenching). Bioengineering techniques that should be considered include hardening the banks with crib-walls and or layered vegetation (matts).
    - Alignment – will be as close as possible to perpendicular to the road, but will account for existing up-gradient and down-gradient meander which may require a modified alignment. Downstream bank stabilization using natural channel design techniques will be considered, in addition to similar upstream treatment, if needed to ensure stability of the downstream channel banks based on the assessment of the fluvial geomorphologist.
    - Low flow channel – within the open bottom of the crossing, a low flow channel will be established to convey baseflow.
    - Wet swales or sediment traps – to address sediment issues and channel erosion where roadside conveyance and the channel converge. Wet swales or sediment traps in the ditches before discharge locations into the main channel are recommended.

  - Capacity – to meet MTO criteria for passing a 50-year flow. Conservation Halton has requested that the Region consider an ultimate culvert design that keeps Ninth Line road surface flood free under Regional Storm conditions.
- There are three other existing minor discharge locations where runoff from the road right of way and up-gradient lands discharge to the west. One new crossing will also be constructed. Down gradient channels from these crossings should be assessed to ensure channel stability. Preliminary sizes of culverts for these minor crossings were assessed to ensure they will be able to convey peak flow from a 25 year storm as per MTO requirements. At locations where large or twin culverts are needed, Conservation Halton has requested consideration be given to a box culvert to provide more effective flow and channel characteristics for the watercourse feature.
- The road widening will increase the impervious Ninth Line road surface area from 2.2% of the study area to 4.5% of the 457ha study drainage area. The proposed road work is expected to have a negligible effect (around 1%) on peak flow rates following road widening compared to existing conditions.
- The proposed road re-design will provide, at a minimum, enhanced level of treatment for an area equivalent to the additional impervious area from the road widening and where possible, the existing road surface area.
- The existing ditch system will be replaced with a new drainage system that will include shallow sloped, vegetated trapezoidal ditches, and underground pipes in locations where insufficient right of way exists for ditches. This trapezoidal ditches are intended to provide quality and quantity control for stormwater runoff. A treatment train approach will be used that includes additional stormwater management features such as strategically placed oil-grit separators, sediment traps and/or wet swales, check dams, and implementation of Low Impact Development Techniques (e.g., porous buffer strip and strategic use of pervious pavement for the bike lanes in the Semi Rural cross section, tree pits, bio-retention areas). Conservation Halton recommends that discussions between the designing Landscape Architect and Engineer take place at the onset of the detailed design process to refine LID options.
- Inlet and outlet channel stabilization works at the Main Culvert (5+180) will need to occur outside of the 42m right-of-way.

Modelling and sizing of drainage infrastructure in this report is preliminary in nature to assess general feasibility of proposed stormwater plans. For final design, additional detailed assessment recommended is including:

- Develop a Visual HYMO (or equivalent) model of the entire study area and up gradient tributary areas to provide flow rates for existing and proposed conditions at all existing and proposed crossings.
- Continue to develop the HEC-RAS model for the site including the crossings at Stn 1+238 and Stn. 3+498.
- Detailed design of all culverts, ditches and storm sewers to meet all Town of Halton Hills and MTO design requirements.

In support of detailed design for the entire Ninth Line study corridor, the following additional fluvial geomorphic assessments are recommended:

- Meander Belt and Width Change Assessment of existing channel based on historical imagery.

- Rapid Geomorphic Assessment (RGA) of channel downstream of the existing main culvert crossing to convergence with tributary west of Ninth Line, to assess stability of downstream channel.
- Rapid Geomorphic Assessment (RGA) of minor channels associated with the two minor crossing that will be retained in the final design (at Stn. 1+238 and Stn. 3+498).

Additionally, a fluvial geomorphologist should provide advice and design guidance on:

- proposed main culvert width in relation to bankfull width and potential meander melt migration;
- channel base and low flow channel configuration through proposed new culvert;
- proposed bank stabilization design upstream and downstream of proposed main culvert;
- contraction pool design upstream of proposed main culvert; and
- sediment trap design at ditch and channel locations;
- channel stabilization downstream of proposed new culvert crossing at 0+408.

Respectfully Submitted

Urban & Environmental Management Inc.

LICENSED PROFESSIONAL ENGINEER

BGall

R. A. B. GALL

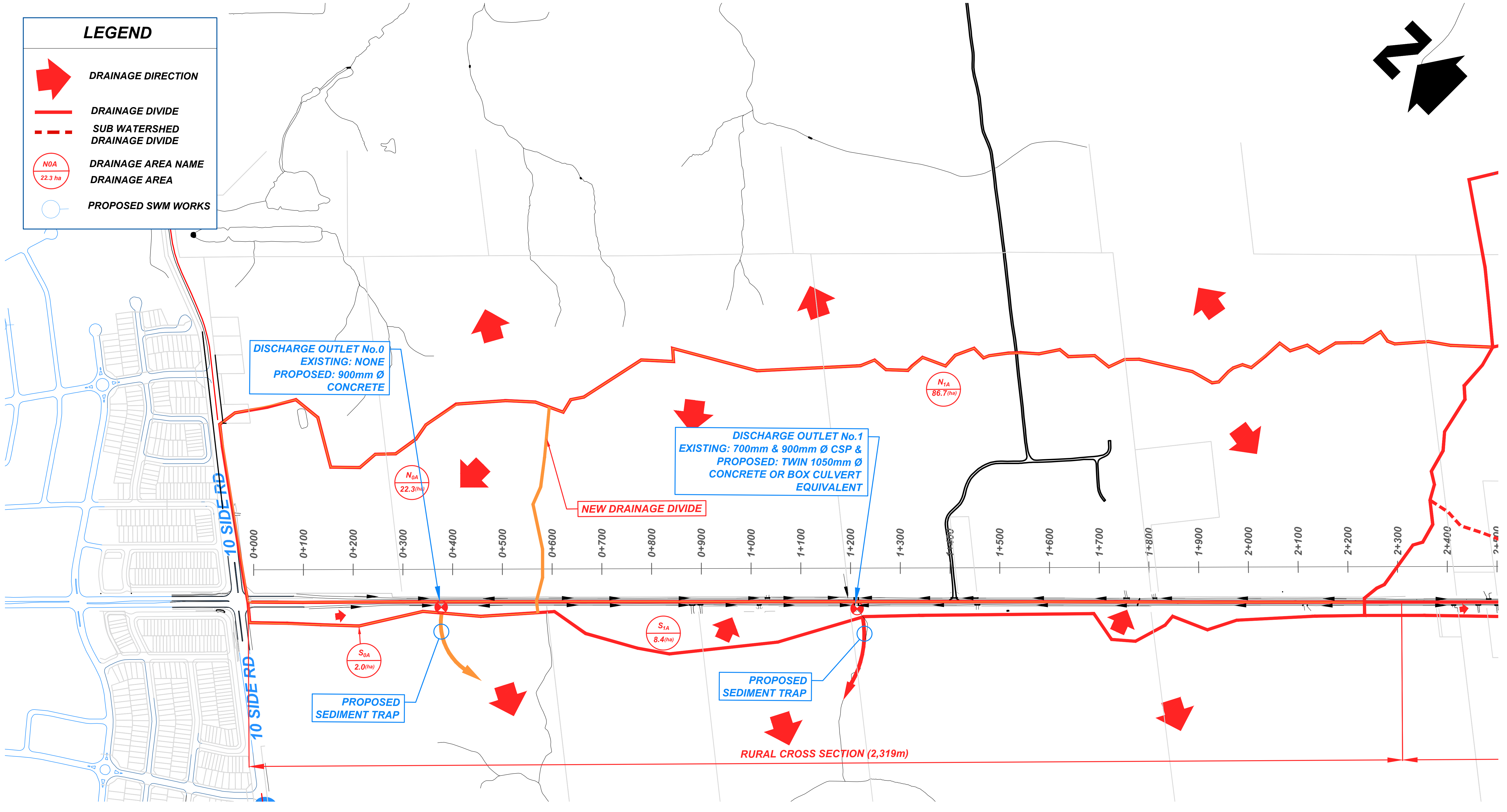
May 4 2016

PROVINCE OF ONTARIO

Bruce Gall, M. Eng., P. Eng.

APPENDIX A
Drainage Area Plans

UTM NAD 83 Zone 17N Projection. Data Sources: Aerial Orthoimagery, Regional Municipality of Niagara
N.B. Mapping is prepared using compiled and calculated information, not from actual surveys. All lot lines are thus +/-.



0	DATE	REVISION DESCRIPTION	0	0	DSGN	0
					DR	0
					CHK	0
No.	DATE	REVISION	BY	APVD	APVD	0

NOTES
1. The position of pole lines, conduits, watermains, sewers, and other underground and above ground utilities and structures is not necessarily shown on the contract drawings, and, where shown the accuracy of the postion of such uitlities and structures is not guaranteed. Before starting work, the contractor shall identify the exact location of all such utilities and structures and shall assume liability for damage to them.
2. Check all dimensions and report any inconsistencies to the Engineer before proceding with the work – DO NOT SCALE DRAWINGS.
3. This drawing is an instrument of Professional Service and is intended for use only in connection with the project covered by the Engineering Agreement
4. Urban & Environmental Management Inc., does not assume any responsibility for losses, damages, and costs arising from use or misuse of this drawing by persons, firms, or corporations without prior written consent of Urban & Environmental Management Inc.
5. Copyright Urban & Environmental Management Inc., 2008. All rights reserved. No part of this drawing may be reproduced in any form or by any means without the written permission of Urban & Environmental Management Inc.

UEM URBAN & ENVIRONMENTAL MANAGEMENT INC.
PROFESSIONAL CONSULTING SERVICES

Halton REGION

REGIONAL MUNICIPALITY OF HALTON

PROPOSED DRAINAGE PLAN
FIGURE No.1
STA 0+000 - 2+500

PROJ No. 14–508 | DATE 2016–01–27 | SCALE 1:7500

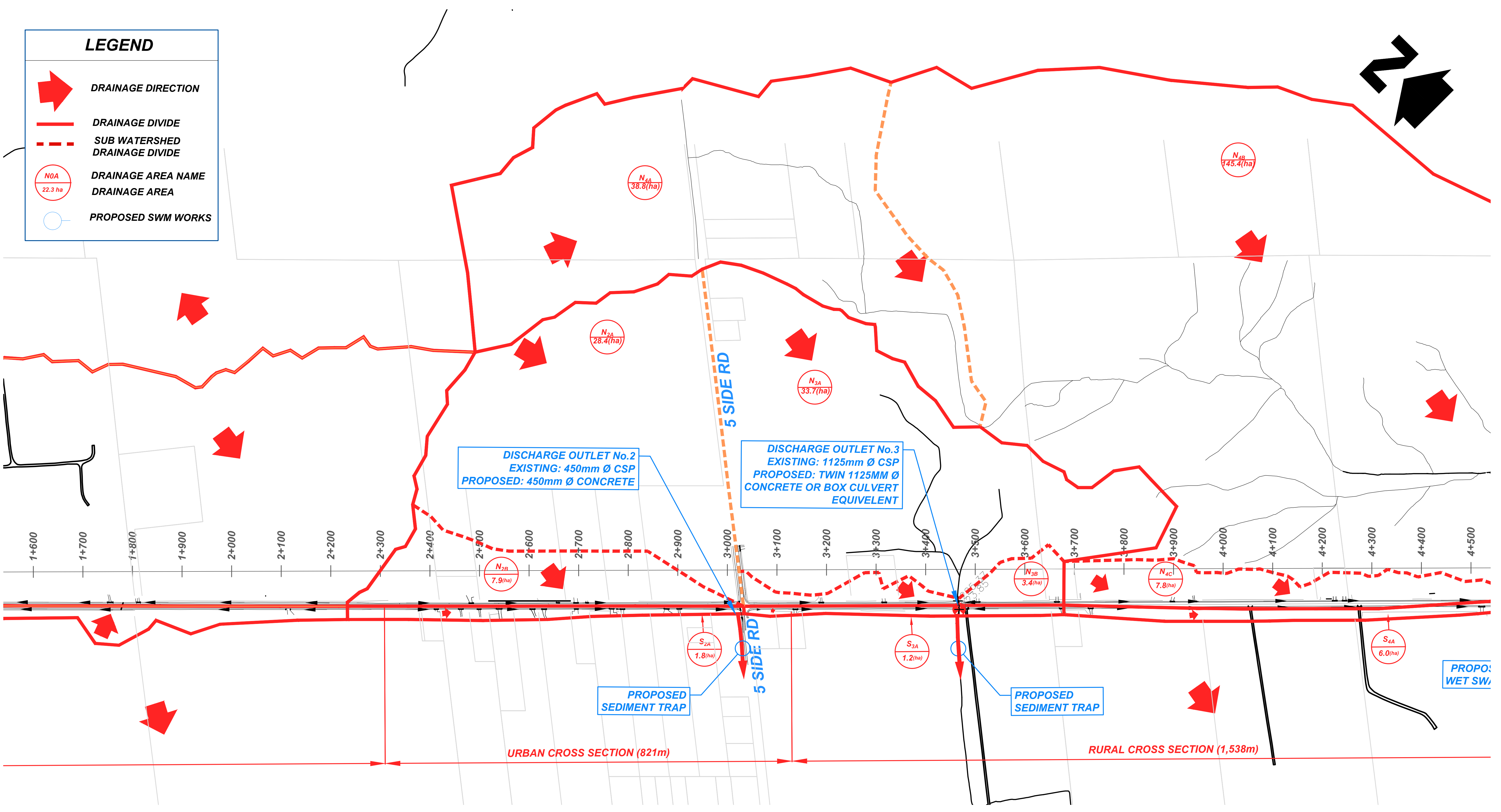
PROJ No. 14-508

UEM

File: Z:\UEM\Projects\2014\500\14–508 Ninth Line Class EA\CAD\BASEPLAN 3D 20151120 [CH catchments areas ED].dwg

Plotted: Mar 02, 2016 – 3:04pm

UTM NAD 83 Zone 17N Projection. Data Sources: Aerial Orthoimagery, Regional Municipality of Niagara
N.B. Mapping is prepared using compiled and calculated information, not from actual surveys. All lot lines are thus +/-.



0	DATE	REVISION DESCIPTION	0	0	DSGN	0
					DR	0
					CHK	0
No.	DATE	REVISION	BY	APVD	APVD	0

NOTES
1. The position of pole lines, conduits, watermains, sewers, and other underground and above ground utilities and structures is not necessarily shown on the contract drawings, and, where shown the accuracy of the postion of such uitlities and structures is not guaranteed. Before starting work, the contractor shall identify the exact location of all such utilities and structures and shall assume liability for damage to them.
2. Check all dimensions and report any inconsistencies to the Engineer before proceding with the work – DO NOT SCALE DRAWINGS.
3. This drawing is an instrument of Professional Service and is intended for use only in connection with the project covered by the Engineering Agreement
4. Urban & Environmental Management Inc., does not assume any responsibility for losses, damages, and costs arising from use or misuse of this drawing by persons, firms, or corporations without prior written consent of Urban & Environmental Management Inc.
5. Copyright Urban & Environmental Management Inc., 2008. All rights reserved. No part of this drawing may be reproduced in any form or by any means without the written permission of Urban & Environmental Management Inc.

UEM URBAN & ENVIRONMENTAL MANAGEMENT INC.
PROFESSIONAL CONSULTING SERVICES

Halton REGION

REGIONAL MUNICIPALITY OF HALTON

PROPOSED DRAINAGE PLAN
FIGURE No.2
STA 1+600 - 4+500

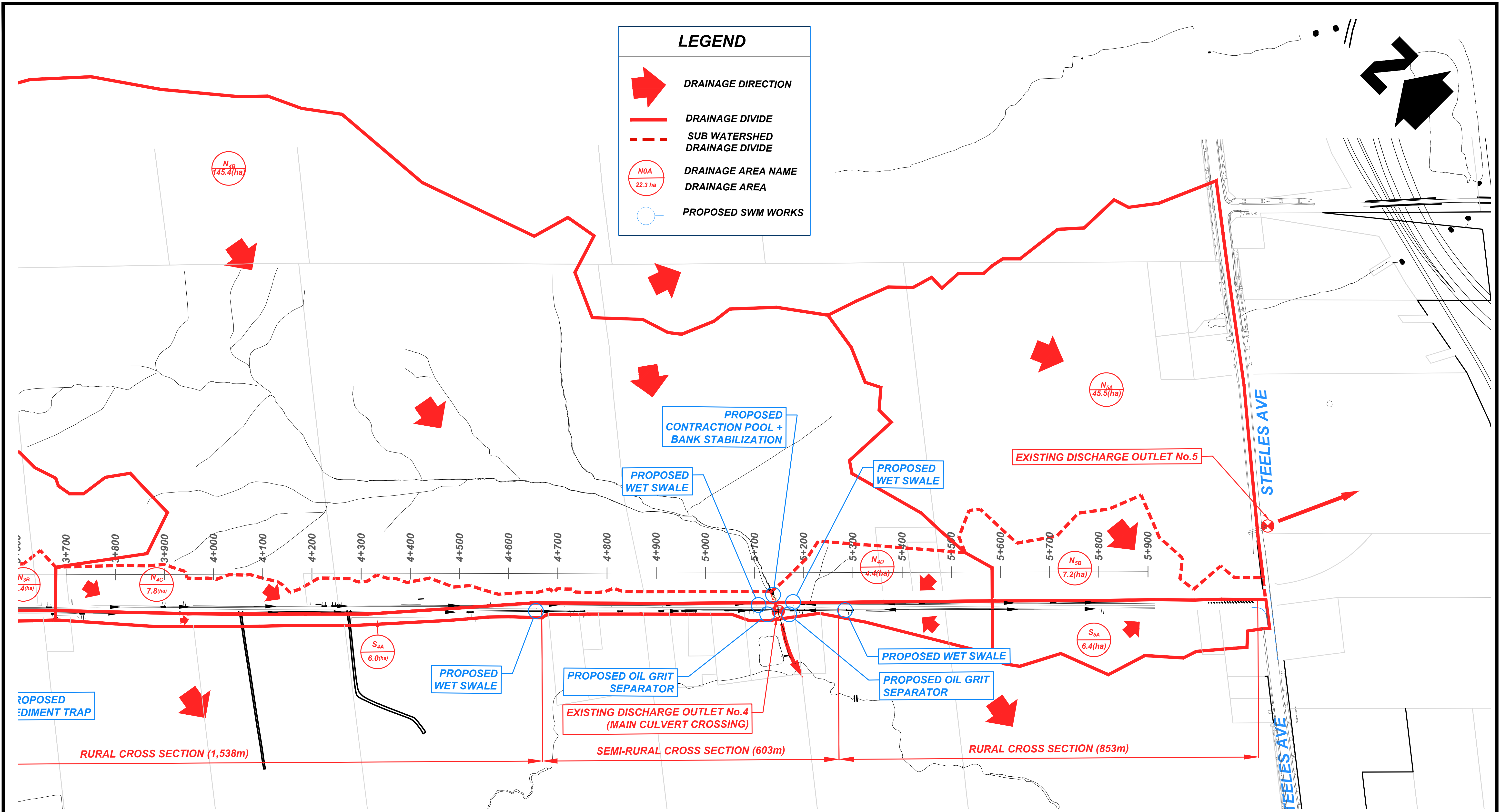
PROJ No. 14–508 DATE 2016–01–27 SCALE 1:7500

PROJ No. 14-508

UEM

File: Z:\UEM\Projects\2014\500\14–508 Ninth Line Class EA\CAD\BASEPLAN 3D 20160428 [CH catchments areas ED].dwg

Plotted: Apr 28, 2016 – 1:12pm



UTM NAD 83 Zone 17N Projection. Data Sources: Aerial Orthoimagery, Regional Municipality of Niagara

N.B. Mapping is prepared using compiled and calculated information, not from actual surveys. All lot lines are thus +/-.

PROJ No. 14-508

0	DATE	REVISION DESCIPTION	0	0	DSGN	0
					DR	0
					CHK	0
No.	DATE	REVISION	BY	APVD	APVD	0

NOTES
1. The position of pole lines, conduits, watermains, sewers, and other underground and above ground utilities and structures is not necessarily shown on the contract drawings, and, where shown the accuracy of the postion of such uitlities and structures is not guaranteed. Before starting work, the contractor shall identify the exact location of all such utilities and structures and shall assume liability for damage to them.
2. Check all dimensions and report any inconsistencies to the Engineer before proceding with the work – DO NOT SCALE DRAWINGS.
3. This drawing is an instrument of Professional Service and is intended for use only in connection with the project covered by the Engineering Agreement
4. Urban & Environmental Management Inc., does not assume any responsibility for losses, damages, and costs arising from use or misuse of this drawing by persons, firms, or corporations without prior written consent of Urban & Environmental Management Inc.
5. Copyright Urban & Environmental Management Inc., 2008. All rights reserved. No part of this drawing may be reproduced in any form or by any means without the written permission of Urban & Environmental Management Inc.

UEM URBAN & ENVIRONMENTAL MANAGEMENT INC.
PROFESSIONAL CONSULTING SERVICES

Halton REGION

REGIONAL MUNICIPALITY OF HALTON

PROPOSED DRAINAGE PLAN
FIGURE No.3
STA 3+600 - 5+900

PROJ No. 14–508 | DATE 2016–01–27 | SCALE 1:7500

Plotted: Mar 02, 2016 – 2:54pm File: Z:\UEM\Projects\2014\500\14-508 Ninth Line Class EA\CAD\BASEPLAN 3D 20151120 [CH catchments areas ED].dwg

APPENDIX B
Town of Halton Hills Rainfall Statistics

INTENSITY-DURATION-FREQUENCY

Compilation of A.E.S. Hydrometeorology Division data for Toronto International Airport, Fergus Shand Dam and Heart Lake (weighted by total years of record)

INTENSITY (mm/h) - (RAINFALL AMOUNT - (mm))

Duration (min)	FREQUENCY					
	2 year	5 year	10 year	25 year	50 year	100 year
5	104.64 (8.72)	135.36 (11.28)	155.64 (12.97)	181.44 (15.12)	200.40 (16.70)	219.36 (18.28)
10	73.08 (12.18)	94.68 (15.78)	109.02 (18.17)	127.08 (21.18)	140.46 (23.41)	153.78 (25.63)
15	61.60 (15.40)	82.88 (20.72)	97.04 (24.26)	114.84 (28.71)	128.08 (32.02)	141.24 (35.31)
30	41.22 (20.61)	56.96 (28.48)	67.40 (33.70)	80.58 (40.29)	90.32 (45.16)	100.06 (50.03)
60	24.23 (24.23)	35.32 (35.32)	42.68 (42.68)	51.97 (51.97)	58.85 (58.85)	65.69 (65.69)
120	14.73 (29.45)	21.23 (42.45)	25.54 (51.07)	30.98 (61.95)	35.01 (70.01)	39.02 (78.03)
360	6.51 (39.05)	9.11 (54.63)	10.83 (64.96)	13.00 (78.00)	14.61 (87.67)	16.22 (97.29)
720	3.76 (45.16)	5.21 (62.49)	6.17 (73.98)	7.37 (88.49)	8.27 (99.25)	9.16 (109.95)
1440	2.44 (58.49)	3.01 (72.21)	3.56 (85.50)	4.26 (102.26)	4.78 (114.69)	5.29 (127.05)

CHICAGO RAINFALL DISTRIBUTION

$$I = A (B + td)^{C}$$

A	586.10	946.46	1173.48	1368.91	1622.45	1777.20
B	6.0	7.0	8.0	8.0	9.0	9.0
C	-.760	-.788	-.794	-.789	-.797	-.795

TOWN OF HALTON HILLS

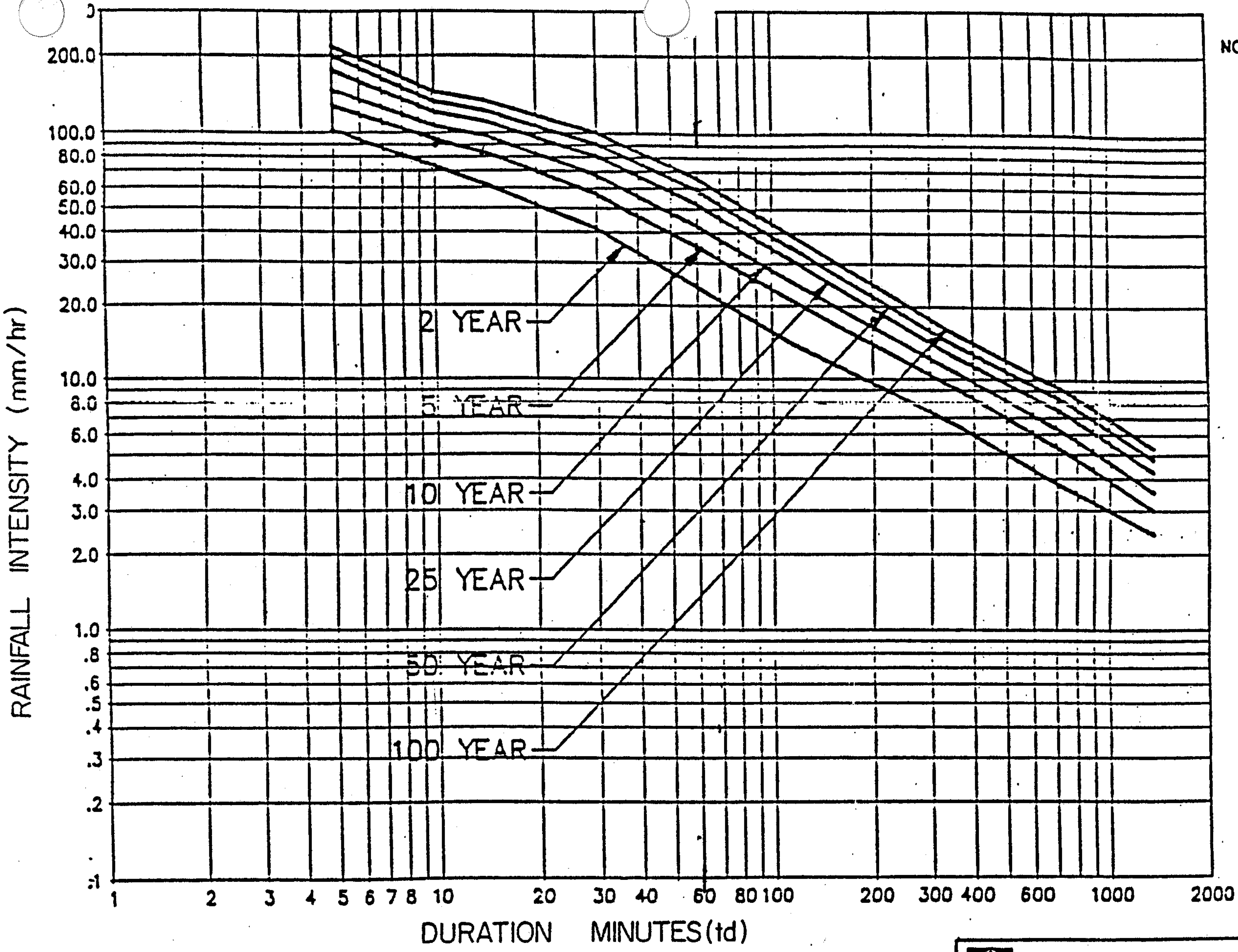
INTENSITY DURATION FREQUENCY
CHICAGO RAINFALL DISTRIBUTION

DRAWN: GDM
CHK'D:
DATE: 88-06-01
TOWN ENGINEER

NO.	DATE	REVISION

STD NO. 108

COUNCIL APPROVAL 88-06-13



NOTE: For area ≤ 20 ha

STD NO 105

TOWN OF HALTON HILLS

SHORT DURATION RAINFALL INTENSITY-DURATION-FREQUENCY

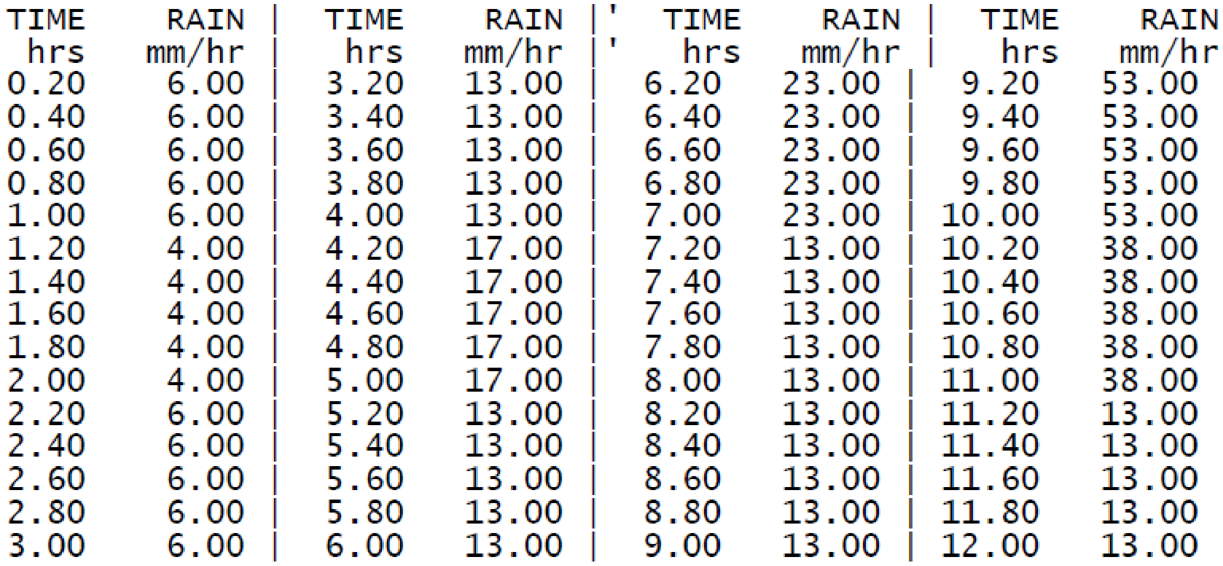
DRAWN GDM	CHK'D:
DATE 88-06-01	
TOWN ENGINEER	

NO	DATE	REVISION

STD NO 105

COUNCIL APPROVAL 88-06-13

Regional Storm – Hurricane Hazel – Final 12 Hours (212mm over final 12 hours of storm)

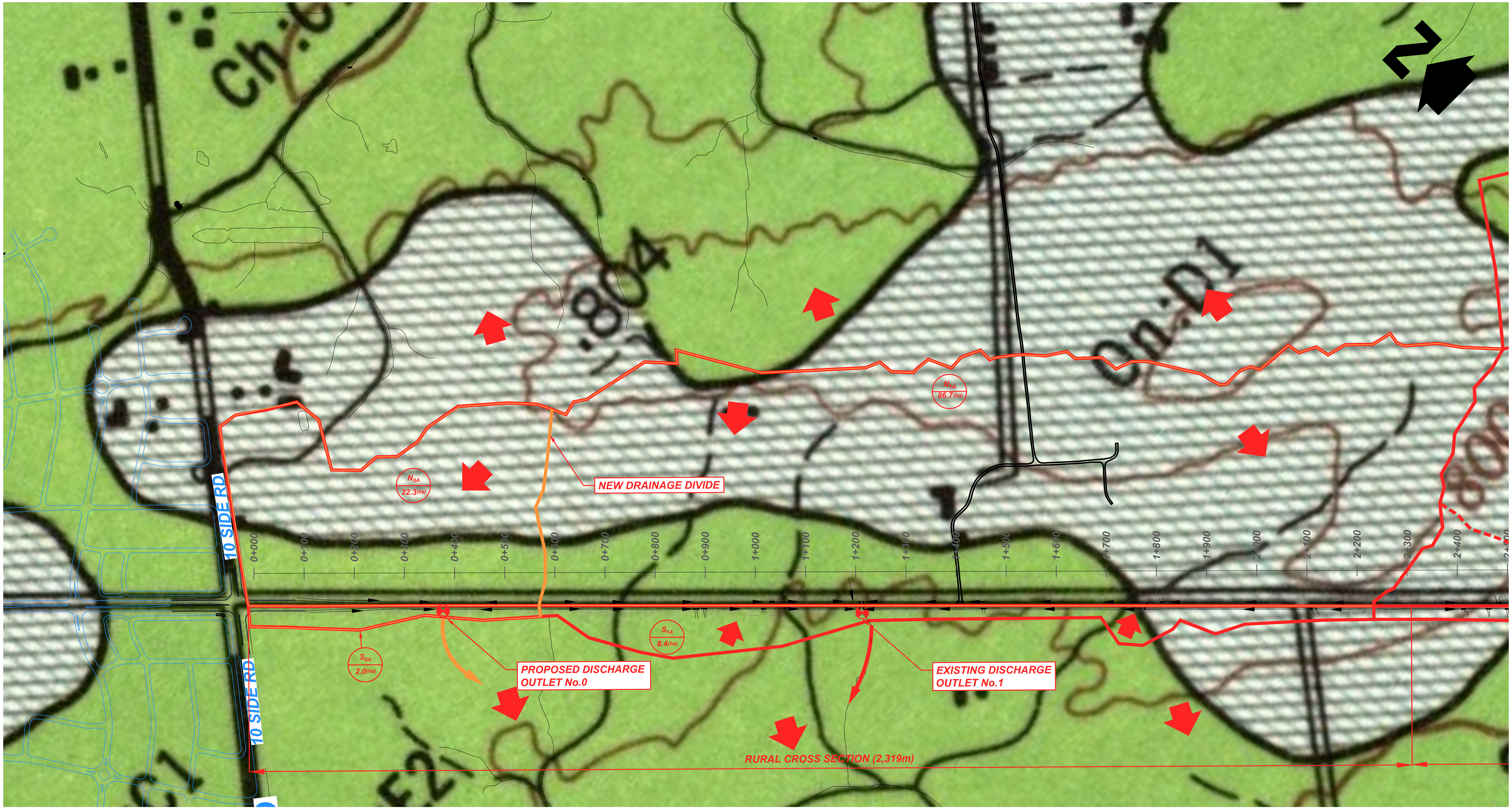


```
TIME      RAIN |  TIME      RAIN |'  TIME      RAIN |  TIME      RAIN
 hrs     mm/hr |   hrs     mm/hr |'   hrs     mm/hr |   hrs     mm/hr
0.20      6.00 |  3.20     13.00 |  6.20     23.00 |  9.20     53.00
0.40      6.00 |  3.40     13.00 |  6.40     23.00 |  9.40     53.00
0.60      6.00 |  3.60     13.00 |  6.60     23.00 |  9.60     53.00
0.80      6.00 |  3.80     13.00 |  6.80     23.00 |  9.80     53.00
1.00      6.00 |  4.00     13.00 |  7.00     23.00 | 10.00     53.00
1.20      4.00 |  4.20     17.00 |  7.20     13.00 | 10.20     38.00
1.40      4.00 |  4.40     17.00 |  7.40     13.00 | 10.40     38.00
1.60      4.00 |  4.60     17.00 |  7.60     13.00 | 10.60     38.00
1.80      4.00 |  4.80     17.00 |  7.80     13.00 | 10.80     38.00
2.00      4.00 |  5.00     17.00 |  8.00     13.00 | 11.00     38.00
2.20      6.00 |  5.20     13.00 |  8.20     13.00 | 11.20     13.00
2.40      6.00 |  5.40     13.00 |  8.40     13.00 | 11.40     13.00
2.60      6.00 |  5.60     13.00 |  8.60     13.00 | 11.60     13.00
2.80      6.00 |  5.80     13.00 |  8.80     13.00 | 11.80     13.00
3.00      6.00 |  6.00     13.00 |  9.00     13.00 | 12.00     13.00
```

APPENDIX C
Soils Data

UTM NAD 83 Zone 17N Projection. Data Sources: Aerial Orthoimagery, Regional Municipality of Niagara
N.B. Mapping is prepared using compiled and calculated information, not from actual surveys. All lot lines are thus +/-.

PROJ No. 14-508



0	DATE	REVISION DESCRIPTION	0	0	DSGN	0
					DR	0
					CHK	0
No.	DATE	REVISION	BY	APVD	APVD	0

NOTES
1. The position of pole lines, conduits, watermains, sewers, and other underground and above ground utilities and structures is not necessarily shown on the contract drawings, and, where shown the accuracy of the postion of such uitlities and structures is not guaranteed. Before starting work, the contractor shall identify the exact location of all such utilities and structures and shall assume liability for damage to them.
2. Check all dimensions and report any inconsistencies to the Engineer before proceding with the work – DO NOT SCALE DRAWINGS.
3. This drawing is an instrument of Professional Service and is intended for use only in connection with the project covered by the Engineering Agreement
4. Urban & Environmental Management Inc., does not assume any responsibility for losses, damages, and costs arising from use or misuse of this drawing by persons, firms, or corporations without prior written consent of Urban & Environmental Management Inc.
5.

URBAN & ENVIRONMENTAL MANAGEMENT INC.
PROFESSIONAL CONSULTING SERVICES

Halton REGION

REGIONAL MUNICIPALITY OF HALTON

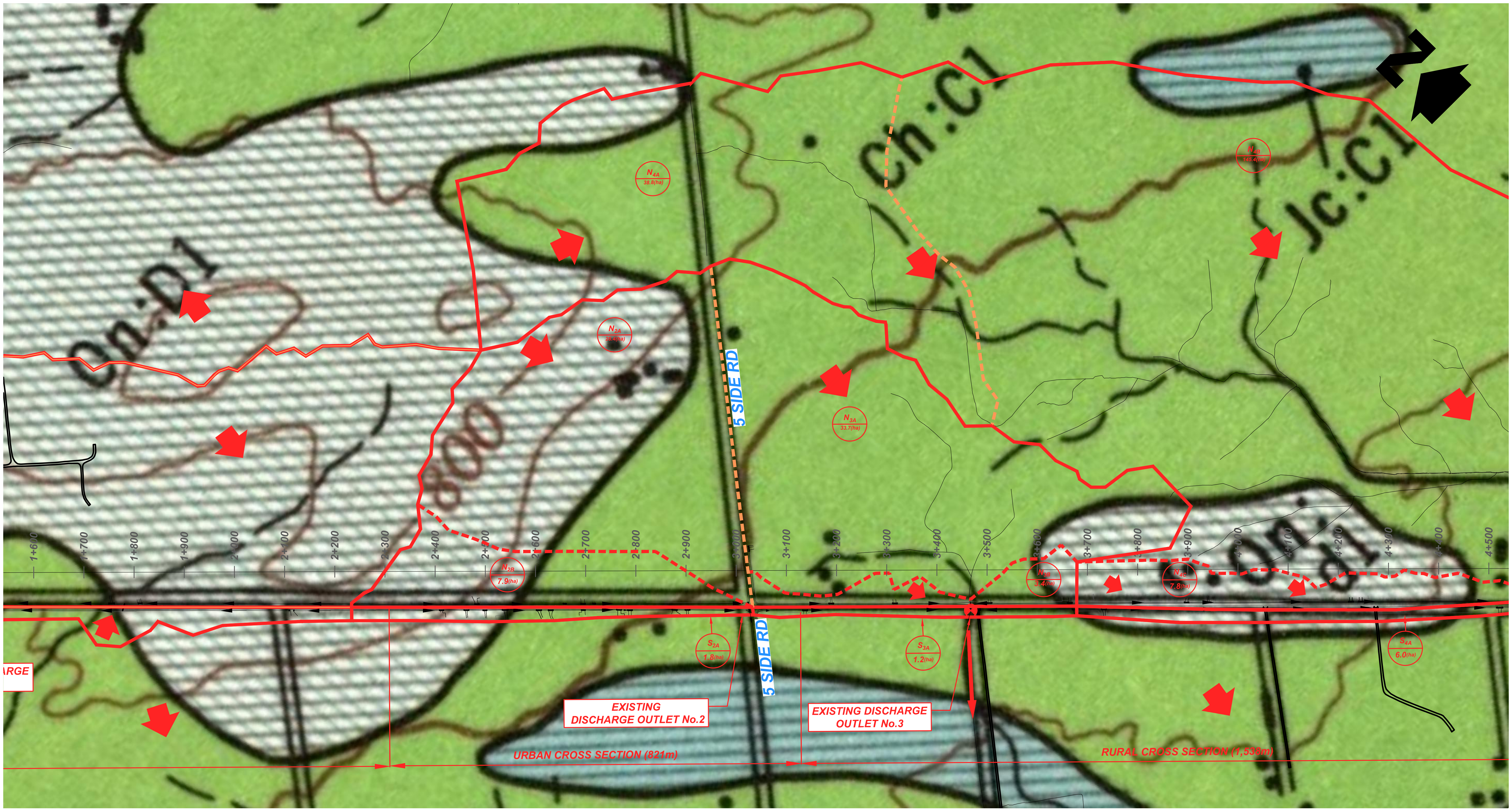
PROPOSED DRAINAGE PLAN
FIGURE No.1
STA 0+000 - 2+500

PROJ No. 14–508	DATE 2016–05–04	SCALE 1:7500

File: Z:\UEM\Projects\2014\500\14–508 Ninth Line Class EA\3.Technical_Analyses\SWM and Drainage\Soils CAD\Soils + catchments areas ED – Dec 21.dwg

Plotted: May 04, 2016 – 2:19pm

UTM NAD 83 Zone 17N Projection. Data Sources: Aerial Orthoimagery, Regional Municipality of Niagara
N.B. Mapping is prepared using compiled and calculated information, not from actual surveys. All lot lines are thus +/-.



0	DATE	REVISION DESCRIPTION	0	0
No.	DATE	REVISION	BY	APVD

DSGN 0
DR 0
CHK 0
APVD 0

NOTES
1. The position of pole lines, conduits, watermains, sewers, and other underground and above ground utilities and structures is not necessarily shown on the contract drawings, and, where shown the accuracy of the postion of such uitlities and structures is not guaranteed. Before starting work, the contractor shall identify the exact location of all such utilities and structures and shall assume liability for damage to them.
2. Check all dimensions and report any inconsistencies to the Engineer before proceding with the work – DO NOT SCALE DRAWINGS.
3. This drawing is an instrument of Professional Service and is intended for use only in connection with the project covered by the Engineering Agreement
4. Urban & Environmental Management Inc., does not assume any responsibility for losses, damages, and costs arising from use or misuse of this drawing by persons, firms, or corporations without prior written consent of Urban & Environmental Management Inc.
5. Copyright Urban & Environmental Management Inc., 2008. All rights reserved. No part of this drawing may be reproduced in any form or by any means without the written permission of Urban & Environmental Management Inc.

UEM URBAN & ENVIRONMENTAL MANAGEMENT INC.
PROFESSIONAL CONSULTING SERVICES

Halton REGION

REGIONAL MUNICIPALITY OF HALTON

PROPOSED DRAINAGE PLAN
FIGURE No.2
STA 1+600 - 4+500

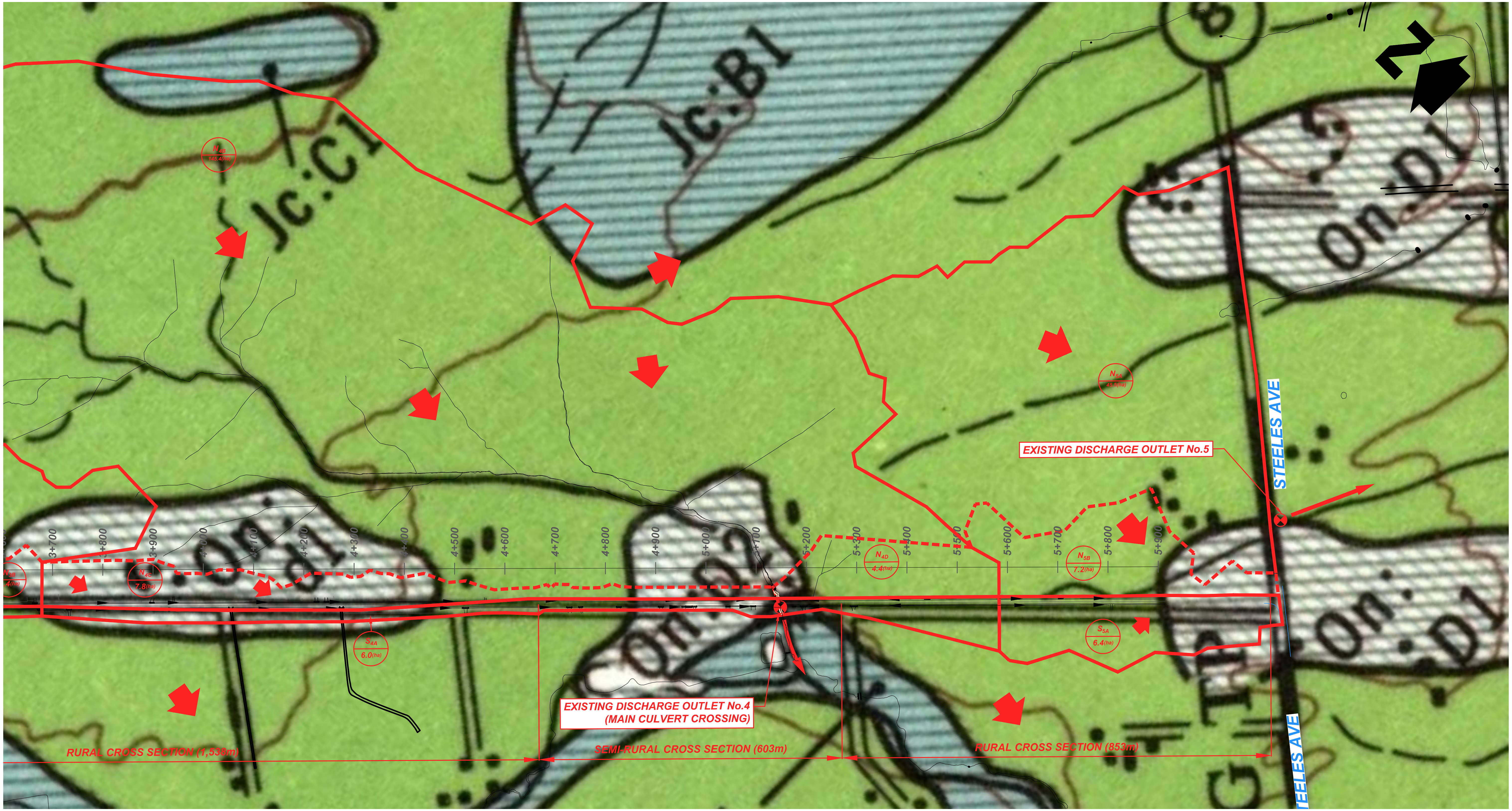
PROJ No. 14–508
DATE 2016–05–04
SCALE 1:7500

PROJ No. 14-508

File: Z:\UEM\Projects\2014\500\14–508 Ninth Line Class EA\3.Technical_Analyses\SWM and Drainage\Soils CAD\Soils + catchments areas ED – Dec 21.dwg
Plotted: May 04, 2016 – 2:19pm

UTM NAD 83 Zone 17N Projection. Data Sources: Aerial Orthoimagery, Regional Municipality of Niagara
N.B. Mapping is prepared using compiled and calculated information, not from actual surveys. All lot lines are thus +/-.

PROJ No. 14-508



0	DATE	REVISION DESCIPTION	0	0
No.	DATE	REVISION	BY	APVD

DSGN 0
DR 0
CHK 0
APVD 0

NOTES
1. The position of pole lines, conduits, watermains, sewers, and other underground and above ground utilities and structures is not necessarily shown on the contract drawings, and, where shown the accuracy of the postion of such uitlities and structures is not guaranteed. Before starting work, the contractor shall identify the exact location of all such utilities and structures and shall assume liability for damage to them.
2. Check all dimensions and report any inconsistencies to the Engineer before proceding with the work – DO NOT SCALE DRAWINGS.
3. This drawing is an instrument of Professional Service and is intended for use only in connection with the project covered by the Engineering Agreement
4. Urban & Environmental Management Inc., does not assume any responsibility for losses, damages, and costs arising from use or misuse of this drawing by persons, firms, or corporations without prior written consent of Urban & Environmental Management Inc.
5. Copyright Urban & Environmental Management Inc., 2008. All rights reserved. No part of this drawing may be reproduced in any form or by any means without the written permission of Urban & Environmental Management Inc.

UEM URBAN & ENVIRONMENTAL MANAGEMENT INC.
PROFESSIONAL CONSULTING SERVICES

Halton REGION

REGIONAL MUNICIPALITY OF HALTON

PROPOSED DRAINAGE PLAN
FIGURE No.3
STA 3+600 - 5+900

PROJ No. 14-508
DATE 2016-05-04
SCALE 1:7500

Plotted: May 04, 2016 – 2:19pm File: Z:\UEM\Projects\2014\500\14-508 Ninth Line Class EA\3.Technical_Analyses\SWM and Drainage\Soils CAD\Soils + catchments areas ED – Dec 21.dwg

Source: Soil Map, Halton County, Ontario . Soil Survey Report 43

LEGEND

MAP SYMBOL	SOIL TYPE		ACREAGE	GREAT GROUP	PARENT MATERIALS	DRAINAGE CLASS
Be	**BERRIEN**	sandy loam	1,300	Gray Brown Luvisol	Medium sand over clay	Imperfectly drained
Ba	**BRADY**	sandy loam	1,900	Gray Brown Luvisol	Medium sand	Imperfectly drained
Bs	**BRADY**	sandy loam—shallow phase	250	Gray Brown Luvisol	Medium sand over rock	Imperfectly drained
Bl	**BRISBANE**	loam	400	Gray Brown Luvisol	Outwash gravel	Imperfectly drained
Bu	**BURFORD**	loam	4,400	Gray Brown Luvisol	Outwash gravel	Well drained
Br	**BURFORD**	loam—rocky phase	500	Gray Brown Luvisol	Outwash gravel over bedrock	Well drained
B.L.	**BOTTOM LAND**		3,100	Regosol	Recent alluvial	Variable
Cl	**CHINGUACOUSY**	loam	150	Gray Brown Luvisol	Clay loam till	Imperfectly drained
Ch	**CHINGUACOUSY**	clay loam	50,650	Gray Brown Luvisol	Clay loam till	Imperfectly drained
Cr	**CHINGUACOUSY**	clay loam—rocky phase	4,400	Gray Brown Luvisol	Clay loam till over bedrock	Imperfectly drained
Ci	**CHINGUACOUSY**	silt loam	1,750	Gray Brown Luvisol	Silty clay loam till	Imperfectly drained
Cd	**COLWOOD**	loam	700	Humic Gleysol	Water deposited fine sand and silt	Poorly drained
Cs	**COLWOOD**	loam—shallow phase	3,900	Humic Gleysol	Water deposited fine sand and silt over bedrock	Poorly drained
Co	**COLWOOD**	silt loam	1,500	Humic Gleysol	Water deposited fine sand and silt	Poorly drained
Ck	**COOKSVILLE**	clay	450	Gray Brown Luvisol	Gray shale	Moderately well drained
Dk	**DONNYBROOK**	gravelly loam	3,850	Gray Brown Luvisol	Coarse gravel	Well drained
Dl	**DUMFRIES**	loam	16,700	Gray Brown Luvisol	Stony loam till	Well drained
Ds	**DUMFRIES**	loam—shallow phase	50	Gray Brown Luvisol	Stony loam till	Well drained
Dr	**DUMFRIES**	loam—rocky phase	700	Gray Brown Luvisol	Stony loam till	Well drained
Du	**DUMFRIES**	sandy loam	150	Gray Brown Luvisol	Stony loam till	Well drained
Fl	**FARMINGTON**	loam	7,100	Melanic Brunisol	Shallow loam till	Variable
Fr	**FARMINGTON**	loam—rocky phase	6,350	Melanic Brunisol	Shallow loam till	Variable
Fo	**FONT**	sandy loam	10,800	Gray Brown Luvisol	Outwash gravel	Well drained
Fn	**FOX**	sandy loam	4,500	Gray Brown Luvisol	Outwash medium sand	Well drained
Fp	**FOX**	sandy loam—shallow phase	200	Gray Brown Luvisol	Outwash medium sand over bedrock	Well drained
Fs	**FLAMBORO**	sandy loam—shallow phase	50	Humic Gleysol	Outwash medium sand	Poorly drained
Gf	**GILFORD**	loam	700	Humic Gleysol	Outwash gravel	Poorly drained
Gr	**GRANBY**	sandy loam	250	Humic Gleysol	Medium sand	Poorly drained
Gi	**GRIMBSY**	sandy loam	4,800	Gray Brown Luvisol	Medium sand	Well drained
Gp	**GRIMBSY**	sandy loam—shallow phase	50	Gray Brown Luvisol	Medium sand over bedrock	Well drained
Gl	**GUELPH**	loam	17,450	Gray Brown Luvisol	Loam till	Well drained
Gs	**GUELPH**	loam—shallow phase	950	Gray Brown Luvisol	Loam till over bedrock	Well drained
Gu	**GUELPH**	sandy loam	500	Gray Brown Luvisol	Sandy loam till	Well drained
Jc	**JEDDO**	clay loam	14,750	Humic Gleysol	Clay loam till	Poorly drained
Kl	**KILLEAN**	loam	1,650	Gray Brown Luvisol	Stony loam till	Imperfectly drained
Li	**LILY**	loam	2,600	Humic Gleysol	Stony loam till	Poorly drained
Lc	**LOCKPORT**	clay	2,950	Gray Brown Luvisol	Clay till	Moderately well drained

MAP SYMBOL	MISCELLANEOUS MAPPING UNITS	ACREAGE
10	**STREAM COURSES**	50
11	**RAVINES**	1,700
12	**ESCARPMENT**	1,050
13	**ROCKLAND**	1,0 00

Jc:B1

LEGEND

MAP SYMBOL	SOIL TYPE		ACREAGE	GREAT GROUP	PARENT MATERIALS	DRAINAGE CLASS
Ll	**LONDON**	loam	1,300	Gray Brown Luvisol	Loam till	Imperfectly drained
Lo	**LONDON**	silt loam	100	Gray Brown Luvisol	Loam till	Imperfectly drained
Ma	**MARSH**		550			Very poorly drained
Ml	**MORLEY**	clay loam	300	Humic Gleysol	Silty clay loam till	Poorly drained
M	**MESISOL**		5,650	Mesisol		Very poorly drained
Ms	**MESISOL**	shallow phase	450	Mesisol		Very poorly drained
Ol	**ONEIDA**	loam	3,500	Gray Brown Luvisol	Loam till	Well drained
On	**ONEIDA**	clay loam	33,150	Gray Brown Luvisol	Clay loam till	Well drained
Or	**ONEIDA**	clay loam—rocky phase	2,050	Gray Brown Luvisol	Clay loam till over bedrock	Well drained
Oi	**ONEIDA**	silt loam	6,350	Gray Brown Luvisol	Silty clay loam till	Well drained
Pl	**PARKHILL**	loam	700	Humic Gleysol	loam till	Poorly drained
P	**FIBRISOL**		50	Fibrisol		Very poorly drained
Sp	**SPRINGVALE**	sandy loam	800	Gray Brown Luvisol	Outwash sand and gravel	Moderately well drained
Tc	**TRAFALGAR**	clay	1,350	Gray Brown Luvisol	Clay till	Imperfectly drained
Tr	**TRAFALGAR**	silty clay loam	150	Gray Brown Luvisol	Clay till	Imperfectly drained
Tu	**TUSCOLA**	silt loam	500	Gray Brown Luviosl	Water deposited silt	Imperfectly drained
Vi	**VINELAND**	sandy loam	100	Gray Brown Luvisol	Medium sand	Imperfectly drained
Wi	**WINONA**	sandy loam	250	Gray Brown Luvisol	Medium sand over clay till	Imperfectly drained

Table 17 – **Ontario Soil Series and Hydrologic Soil Groups**

SOIL SERIES	HYDROLOGIC SOIL GROUP
Alberton	D
Allendale*	C
Alliston*	B
Almonte	C
Ameliasburg	D
Ancaster	B
Appleton	B
Atherley	D
Ayr	C
Bainsville	C
Balderson	B
Bamford	B
Bancroft	A
Bass	D
Battersea	C
Bearbrook	D
Belmeade	D
Bennington	B
Berriedale	A
Berrien	C
Beverly*	C
Binbrook	C
Blackwell	D
Bolingbroke	A
Bondhead*	B
Bookton	B
Boomer	B
Brady*	B
Brant*	B
Brantford	C
Bridgman	A
Brighton	A
Brisbane*	B
Brockport	B
Brooke	C
Brookston	D
Bucke	B
Burford*	A
Burnbrae	B
Burnstown*	B
Burpee	C
Buzwah*	C
Caistor	C
Caledon	A
Camilla	B
Campbell*	C
Cane*	D
Carp*	C
Casey	B
Cashel	C
Castor*	C
Chesley	D
Chinguacousy*	C
Christy	C
Clyde	D
Codrington	C
Colborne	A
Colwood*	C
Conestoga	B
Conover	C
Cooksville	B
Cramahe	A
Craigleith	C
Crombie	C
Dalton	C
Darlington	B
Deloro*	B
Donald	B
Donnybrook	A
Dorking	D
Dumfries*	A
Dummer*	B
Dundonald	B
Dunedin	C
Eamer	B
Earlton*	B
Eastport	A
Edenvale	C
Eganville*	B
Elderslie	C
Eldorado	B
Ellwood	C
Elmbrook	C
Elmira	C
Elmsley	B
Embro	C
Emily*	B
Englehart	C
Evanturel*	B
Farmington	B
Ferndale	D
Flamboro*	C
Floradale	B
Font	A
Fonthill	A
Fox*	A
Foxboro	C
Franktown	B
Freeport	B
Galesburg	B
Gananoque*	C
Gerow	C
Gilford	C
Gobles	C
Gordon*	D
Granby	C
Grand	B
Grenville*	B
Grimsby*	A
Guelph*	B
Guerin*	B
Gwillimbury	B
Haldimand	C
Hampden	D
Harkaway*	B
Harriston	B
Harrow	A
Havelock	A
Hawkesville	C
Haysville	B
Heidelberg	B
Hendrie	B
Hespeler	C
Hillier	B
Hillsburgh	A
Hinchinbrooke*	C
Honeywood	B
Howland*	B
Huron	C
Innisville	C
Jeddo	D
Kagawong	B
Kars	A
Kelvin	D
Kemble*	C
Kenabeek	C
Killean	B
King	C
Kirkland	A
Kossuth	B
L'Achigan	B
Lambton	C
Lanark	C
Landsdowne*	D
Leech*	D
Leith	B
Leithrim	B
Lily	C
Lincoln	D
Lindsay*	D
Lisbon	A
Listowel	B
Little Current	B
Lockport	B
London*	B
Lonsdale	D
Lovering	C
Lowbanks	B
Lyons*	C
Macton	B
Magnetawan	C
Mallard*	B
Malton	D
Mannheim	B
Manotick	B
Maplewood	C
Marionville	C
Marsh	D
Maryhill	C
Matilda	B
Matson	C
Medonte	C
Miami	C
Mill	C
Milliken	B
Minesing	D
Mississauga	D
Monaghan	C
Monteagle*	B
Morley	D
Morrisburg	C
Moscow*	D
Mountain	C
Muck	D
Muriel	C
Murray	C
Napanee*	D
Nelson	C
Newburgh	B
Newcastle	B
Niagara	C
Nipissing	C
Norham	B
Normandale	B
North Gower*	D
Oakland	B
Oakview	D
Oneida	C
Ontario	C
Osgoode	C
Oshtemo	A
Osnabruck	D
Osprey	B
Otonabee*	B
Otterskin	C
Parkhill*	C
Peat	D
Peel	C
Pelham	A
Perch	D
Percy	B
Perth	C
Petherwick	C
Phipps*	D
Piccadilly	D
Pike	C
Pike Lake	A
Plainfield	A
Pontypool	A
Preston	B
Renfrew	D
Rideau	D
Rubicon*	B
Sargent	A
Saugeen	C
Schomberg	C
Scotland	A
Seely's Bay	C
Senaca	B
Shashawandah	B
Sidney*	D
Silver Hill	B
Simcoe	D
Smithfield	C
Smithville	C
Snedden	D
Solmesville	C
South Bay	C
Springvale	A
St. Clements	C
St. Jacobs	A
St. Peter	A
Ste. Rosalie	D
St. Samuel*	C
St. Thomas	A
St. Williams	B
Stafford	B
Stockdale	C
Styx	B
Sullivan	A
Tansley	C
Tavistock	C
Tecumseh	B
Teeswater	B
Tennyson*	B
Thames	C
Thorah	C
Thwaites	B
Tioga*	A
Toledo*	D
Trafalgar	B
Trent	C
Tuscola*	C
Tweed	B
Uplands	A
Vanessa	C
Vars	B
Vasey*	B
Vincent	C
Vineland*	B
Vittoria	C
Wabi	B
Walshear	C
Walsingham	A
Waterloo	A
Watford	A
Watrin	C
Waupoos	C
Wauseon	C
Wayside	B
Welland	D
Wellesley	C
Wemyss	B
Wendigo	A
Wendover	D
Westmeath	A
Whitby	B
White Lake*	A
Whitfield	B
Wiarton	B
Wilmot	D
Wilsonville	A
Winona	C
Woburn	B
Wolford	C
Wolsey*	D
Wooler	B
Woolwich	B
Wyevale	A

Source: OMAF Publication 29 – Drainage Guide for Ontario

* Soil series having shallow phases over bedrock. The hydrologic grouping for the rocky phases of these soils should be reduced one group (for example a ‘C’ soil is reduced to ‘B’).

Table 3.5 Runoff curve numbers[2]

Runoff curve number for selected agricultural suburban and urban land use (Antecedent moisture condition II and $I_a = 0.2$ S)

LAND USE DESCRIPTION			HYDROLOGIC SOIL GROUP			
			A	B	C	D
Cultivated land[1]:	without conservation treatment		72	81	88	91
	with conservation treatment		62	71	78	81
Pasture or range land:	poor condition		68	79	86	89
	good condition		39	61	74	80
Meadow: good condition			30	58	71	78
Wood or forest land:	thin stand, poor cover, no mulch		45	66	77	83
	good cover[2]		25	55	70	77
Open spaces, lawns, parks, golf courses, cemeteries, etc.						
	good condition: grass cover on 75% or more of the area		39	61	74	80
	fair condition: grass cover on 50% to 75% of the area		49	69	79	84
Commercial and business areas (85% impervious)			89	92	94	95
Industrial districts (72% impervious)			81	88	91	93
Residential: [3]						
	Average lot size	Average % Impervious[4]				
	1/20 hectare or less	65	77	85	90	92
	1/10 hectare	38	61	75	83	87
	3/20 hectare	30	57	72	81	86
	1/5 hectare	25	54	70	80	85
	2/5 hectare	20	51	68	79	84
Paved parking lots, roofs, driveways, etc.[5]			98	98	98	98
Streets and roads:						
	paved with curbs and storm sewers[5]		98	98	98	98
	gravel		76	85	89	91
	dirt		72	82	87	89

---

[1] For a more detailed description of agricultural land use curve numbers refer to National Engineering Handbook, Section 4, Hydrology, Chapter 9, Aug. 1972[3].

[2] Good cover is protected from grazing and litter and brush cover soil.

[3] Curve numbers are computed assuming the runoff from the house and driveway is directed towards the street with a minimum of roof water directed to lawns where additional infiltration could occur.

[4] The remaining pervious areas (lawn) are considered to be in good pasture condition for these curve numbers.

Table 3.6 Curve number relationships for different antecedent moisture conditions

CN for Condition II	CN for Conditions I & III		CN for Condition II	CN for Conditions I & III	
100	100	100	60	40	78
99	97	100	59	39	77
98	94	99	58	38	76
97	91	99	57	37	75
96	89	99	56	36	75
95	87	98	55	35	74
94	85	98	54	34	73
93	83	98	53	33	72
92	81	97	52	32	71
91	80	97	51	31	70
90	78	96	50	31	70
89	76	96	49	30	69
88	75	95	48	29	68
87	73	95	47	28	67
86	72	94	46	27	66
85	70	94	45	26	65
84	68	93	44	25	64
83	67	93	43	25	63
82	66	92	42	24	62
81	64	92	41	23	61
80	63	91	40	22	60
79	62	91	39	21	59
78	60	90	38	21	58
77	59	89	37	20	57
76	58	89	36	19	56
75	57	88	35	18	55
74	55	88	34	18	54
73	54	87	33	17	53
72	53	86	32	16	52
71	52	86	31	16	51
70	51	85	30	15	50
69	50	84			
68	48	84	25	12	43
67	47	83	20	9	37
66	46	82	15	6	30
65	45	82	10	4	22
64	44	81	5	2	13
63	43	80	0	0	0
62	42	79			
61	41	78			

The effective rainfall is defined by the relationship.

$$Q = \frac{(P - I_a)^2}{P + S - I_a} \qquad \text{where } S = [(100/CN) -10]\cdot 25.4$$

The original SCS method assumed the value of I_a to be equal to 0.2 S. However, many engineers have found that this may be overly conservative, especially for moderated rainfall events and low CN values. Under these conditions the I_a value may be reduced to be a lesser percentage of S or may be estimated and input directly to the above equation.

The Horton Infiltration Equation

The Horton equation[9], which defines the infiltration capacity of the soil, changes the initial rate, f_o, to a lower rate, f_c. The infiltration capacity is an

APPENDIX D
Main Culvert Crossing Assessment Data

Visual HYMO Inputs

Time to Peak Calculation

Discharge (	Location	Catchments	Area (ha)	Road L (m)	Half Road Width (m) Paved	Half Road Width (m) Unpaved	Road Runoff C	Landuse (ha) Road	Landuse (ha) Cultivd	Catchment Length (m)	Elevation (masl) Ups	Elevation (masl) Dns	Slope (%)	Runoff Coefficent	TC (min) Airport	Time to Peak, N=5
4	5+180	N4A	38.8	0				0.00	38.80	1669.3	252.4	226.6	1.546	0.40	80.76	1.08
		N4B	145.4	0				0.00	145.40	2322.2	236.4	212.5	1.030	0.40	108.91	1.45
		N4C	7.8	1463.8	13.8	1	0.940	2.17	5.63	1499.0	226.8	212	0.986	0.55	69.75	0.93
		N4D	4.4	440.9	13.8	1	0.940	0.65	3.75	493.7	217.8	212	1.181	0.48	42.51	0.57

Road Runoff Coefficient
C paved = 0.95
C buffer = 0.8

C cultivated
C cultivated = 0.4

Note: Runoff coefficient for Tc calc only

Curve Number Calculation (AMC II)

Discharge (	Location	Catchments	Area (ha)	Road L (m)	Half Road Width (m) Paved	Half Road Width (m) Unpaved	Road CN	Landuse (ha) Road	Landuse (ha) Cultivd	CN
4	5+180	N4A	38.8	0				0.00	38.80	88
		N4B	145.4	0				0.00	145.40	88
		N4C	7.8	1463.8	13.8	1	97.3	2.17	5.63	91
		N4D	4.4	440.9	13.8	1	97.3	0.65	3.75	89

Road Curve Number
C paved = 98
C buffer = 88

Cultivated CN AMC II (see Appendix C - Soils)
CN cultivated = 88

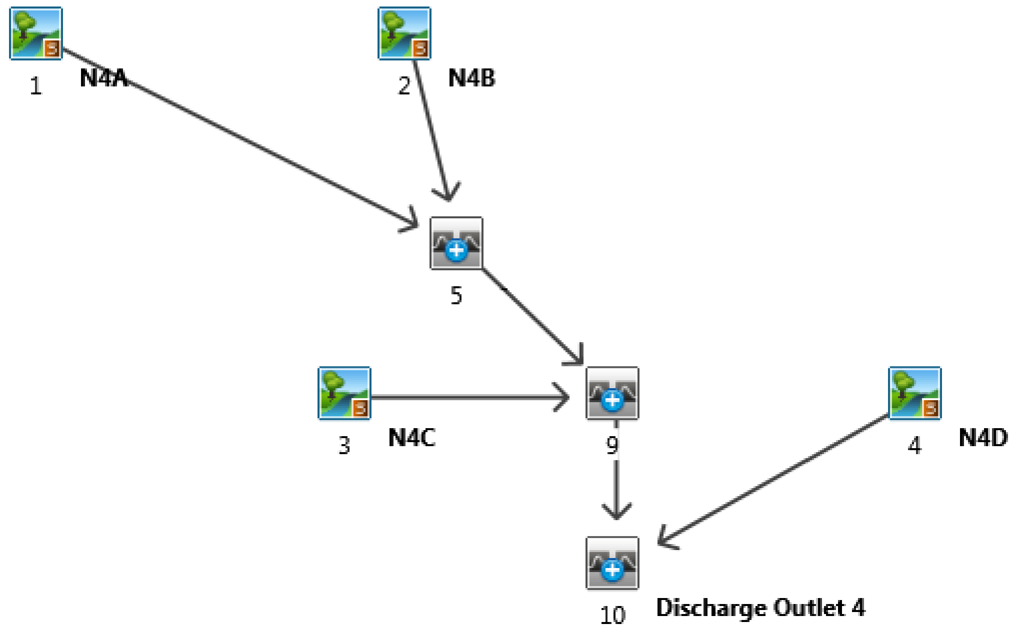
Curve Number Calculation (AMC III)

Discharge (	Location	Catchments	Area (ha)	Road L (m)	Half Road Width (m) Paved	Half Road Width (m) Unpaved	Road CN	Landuse (ha) Road	Landuse (ha) Cultivd	CN
4	5+180	N4A	38.8	0				0.00	38.80	95
		N4B	145.4	0				0.00	145.40	95
		N4C	7.8	1463.8	13.8	1	97.3	2.17	5.63	96
		N4D	4.4	440.9	13.8	1	97.3	0.65	3.75	95

Road Curve Number
C paved = 98
C buffer = 88

Cultivated CN AMC III (see Appendix C - Soils)
CN cultivated = 95

Visual HYMO Schematic and Output



```
****************************
** SIMULATION NUMBER:   1 **
****************************
--------------------
| MASS STORM       |    Filename: C:\Users\eduva\AppD
|                  |              ata\Local\Temp\
|                  |              d05c0a7a-48aa-45ee-bba7-1e0c56c8fd51\cada437a
| Ptotal= 45.10 mm |    Comments: SCS type 2 mass curve
--------------------
                        Duration of storm    = 11.75 hrs
                        Mass curve time step = 15.00 min

                 TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                  hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
                 0.25    1.13 |  3.25    1.80 |  6.25    8.12 |  9.25    1.58
                 0.50    1.13 |  3.50    1.80 |  6.50    3.61 |  9.50    1.58
                 0.75    1.13 |  3.75    1.80 |  6.75    3.61 |  9.75    1.58
                 1.00    1.13 |  4.00    2.71 |  7.00    2.71 | 10.00    0.90
                 1.25    1.13 |  4.25    2.71 |  7.25    2.71 | 10.25    0.90
                 1.50    1.13 |  4.50    3.61 |  7.50    2.71 | 10.50    0.90
                 1.75    1.13 |  4.75    3.61 |  7.75    2.71 | 10.75    0.90
                 2.00    1.35 |  5.00    5.41 |  8.00    1.58 | 11.00    0.90
                 2.25    1.35 |  5.25    5.41 |  8.25    1.58 | 11.25    0.90
                 2.50    1.35 |  5.50   21.65 |  8.50    1.58 | 11.50    0.90
                 2.75    1.35 |  5.75   59.53 |  8.75    1.58 | 11.75    0.90
                 3.00    1.80 |  6.00    8.12 |  9.00    1.58 |

-------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0001)|   Area    (ha)=  38.80   Curve Number (CN)  = 88.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   1.08

     Ia as  0.2xS     (mm)=   6.927
     Unit Hyd Qpeak  (cms)=   1.981

     PEAK FLOW       (cms)=   0.925 (i)
     TIME TO PEAK    (hrs)=   6.750
     RUNOFF VOLUME    (mm)=  19.797
     TOTAL RAINFALL   (mm)=  44.818
     RUNOFF COEFFICIENT   =   0.442

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

-------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0002)|   Area    (ha)= 145.40   Curve Number (CN)  = 88.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   1.45

     Ia as  0.2xS     (mm)=   6.927
     Unit Hyd Qpeak  (cms)=   5.529

     PEAK FLOW       (cms)=   2.751 (i)
     TIME TO PEAK    (hrs)=   7.000
     RUNOFF VOLUME    (mm)=  19.796
     TOTAL RAINFALL   (mm)=  44.818
     RUNOFF COEFFICIENT   =   0.442

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

-------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0005)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0001):    38.80   0.925     6.75    19.80
      + ID2= 2 (  0002):   145.40   2.751     7.00    19.80
        ===================================================
        ID = 3 (  0005):   184.20   3.594     7.00    19.80

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.

-------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0003)|   Area    (ha)=   7.80   Curve Number (CN)  = 91.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   0.93

     Ia as  0.2xS     (mm)=   5.024
     Unit Hyd Qpeak  (cms)=   0.462

     PEAK FLOW       (cms)=   0.265 (i)
```

```
     TIME TO PEAK    (hrs)=   6.500
     RUNOFF VOLUME    (mm)=  24.399
     TOTAL RAINFALL   (mm)=  44.818
     RUNOFF COEFFICIENT   =   0.544

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0009)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0003):     7.80   0.265     6.50    24.40
      + ID2= 2 (  0005):   184.20   3.594     7.00    19.80
        ====================================================
        ID = 3 (  0009):   192.00   3.790     7.00    19.98

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.

--------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0004)|   Area    (ha)=   4.40   Curve Number (CN)  = 89.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   0.57

     Ia as  0.2xS     (mm)=   6.279
     Unit Hyd Qpeak  (cms)=   0.426

     PEAK FLOW       (cms)=   0.177 (i)
     TIME TO PEAK    (hrs)=   6.000
     RUNOFF VOLUME    (mm)=  21.299
     TOTAL RAINFALL   (mm)=  44.818
     RUNOFF COEFFICIENT   =   0.475

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0010)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0004):     4.40   0.177     6.00    21.30
      + ID2= 2 (  0009):   192.00   3.790     7.00    19.98
        ====================================================
        ID = 3 (  0010):   196.40   3.840     7.00    20.01

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.

--------------------------------------------------------------------------------
****************************
** SIMULATION NUMBER:   2 **
****************************
--------------------
| MASS STORM       |    Filename: C:\Users\eduva\AppD
|                  |              ata\Local\Temp\
|                  |              d05c0a7a-48aa-45ee-bba7-1e0c56c8fd51\1cac424c
| Ptotal= 62.50 mm |    Comments: SCS type 2 mass curve
--------------------
                        Duration of storm    = 11.75 hrs
                        Mass curve time step = 15.00 min

                 TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                  hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
                 0.25    1.56 |  3.25    2.50 |  6.25   11.25 |  9.25    2.19
                 0.50    1.56 |  3.50    2.50 |  6.50    5.00 |  9.50    2.19
                 0.75    1.56 |  3.75    2.50 |  6.75    5.00 |  9.75    2.19
                 1.00    1.56 |  4.00    3.75 |  7.00    3.75 | 10.00    1.25
                 1.25    1.56 |  4.25    3.75 |  7.25    3.75 | 10.25    1.25
                 1.50    1.56 |  4.50    5.00 |  7.50    3.75 | 10.50    1.25
                 1.75    1.56 |  4.75    5.00 |  7.75    3.75 | 10.75    1.25
                 2.00    1.87 |  5.00    7.50 |  8.00    2.19 | 11.00    1.25
                 2.25    1.88 |  5.25    7.50 |  8.25    2.19 | 11.25    1.25
                 2.50    1.88 |  5.50   30.00 |  8.50    2.19 | 11.50    1.25
                 2.75    1.88 |  5.75   82.50 |  8.75    2.19 | 11.75    1.25
                 3.00    2.50 |  6.00   11.25 |  9.00    2.19 |

--------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0001)|   Area    (ha)=  38.80   Curve Number (CN)  = 88.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   1.08
```

```
     Ia as  0.2xS     (mm)=   6.927
     Unit Hyd Qpeak  (cms)=   1.981

     PEAK FLOW       (cms)=   1.616 (i)
     TIME TO PEAK    (hrs)=   6.750
     RUNOFF VOLUME    (mm)=  33.905
     TOTAL RAINFALL   (mm)=  62.109
     RUNOFF COEFFICIENT   =   0.546

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0002)|   Area    (ha)= 145.40   Curve Number (CN)  = 88.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   1.45

     Ia as  0.2xS     (mm)=   6.927
     Unit Hyd Qpeak  (cms)=   5.529

     PEAK FLOW       (cms)=   4.855 (i)
     TIME TO PEAK    (hrs)=   7.000
     RUNOFF VOLUME    (mm)=  33.903
     TOTAL RAINFALL   (mm)=  62.109
     RUNOFF COEFFICIENT   =   0.546

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------


--------------------
| ADD HYD  (  0005)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0001):    38.80   1.616     6.75    33.91
      + ID2= 2 (  0002):   145.40   4.855     7.00    33.90
        ===================================================
        ID = 3 (  0005):   184.20   6.307     7.00    33.90

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.

--------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0003)|   Area    (ha)=   7.80   Curve Number (CN)  = 91.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   0.93

     Ia as  0.2xS     (mm)=   5.024
     Unit Hyd Qpeak  (cms)=   0.462

     PEAK FLOW       (cms)=   0.433 (i)
     TIME TO PEAK    (hrs)=   6.500
     RUNOFF VOLUME    (mm)=  39.649
     TOTAL RAINFALL   (mm)=  62.109
     RUNOFF COEFFICIENT   =   0.638

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------


--------------------
| ADD HYD  (  0009)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0003):     7.80   0.433     6.50    39.65
      + ID2= 2 (  0005):   184.20   6.307     7.00    33.90
        ===================================================
        ID = 3 (  0009):   192.00   6.620     7.00    34.14

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.

--------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0004)|   Area    (ha)=   4.40   Curve Number (CN)  = 89.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   0.57

     Ia as  0.2xS     (mm)=   6.279
     Unit Hyd Qpeak  (cms)=   0.426

     PEAK FLOW       (cms)=   0.307 (i)
     TIME TO PEAK    (hrs)=   6.000
     RUNOFF VOLUME    (mm)=  35.837
     TOTAL RAINFALL   (mm)=  62.109
```

```
     RUNOFF COEFFICIENT   =   0.577

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0010)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0004):     4.40   0.307     6.00    35.84
      + ID2= 2 (  0009):   192.00   6.620     7.00    34.14
        ===================================================
        ID = 3 (  0010):   196.40   6.699     7.00    34.18

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.

--------------------------------------------------------------------------------
****************************
** SIMULATION NUMBER:   3 **
****************************
--------------------
| MASS STORM       |    Filename: C:\Users\eduva\AppD
|                  |              ata\Local\Temp\
|                  |              d05c0a7a-48aa-45ee-bba7-1e0c56c8fd51\78b0a189
| Ptotal= 74.00 mm |    Comments: SCS type 2 mass curve
--------------------
                        Duration of storm    = 11.75 hrs
                        Mass curve time step = 15.00 min

                 TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                  hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
                 0.25    1.85 |  3.25    2.96 |  6.25   13.32 |  9.25    2.59
                 0.50    1.85 |  3.50    2.96 |  6.50    5.92 |  9.50    2.59
                 0.75    1.85 |  3.75    2.96 |  6.75    5.92 |  9.75    2.59
                 1.00    1.85 |  4.00    4.44 |  7.00    4.44 | 10.00    1.48
                 1.25    1.85 |  4.25    4.44 |  7.25    4.44 | 10.25    1.48
                 1.50    1.85 |  4.50    5.92 |  7.50    4.44 | 10.50    1.48
                 1.75    1.85 |  4.75    5.92 |  7.75    4.44 | 10.75    1.48
                 2.00    2.22 |  5.00    8.88 |  8.00    2.59 | 11.00    1.48
                 2.25    2.22 |  5.25    8.88 |  8.25    2.59 | 11.25    1.48
                 2.50    2.22 |  5.50   35.52 |  8.50    2.59 | 11.50    1.48
                 2.75    2.22 |  5.75   97.68 |  8.75    2.59 | 11.75    1.48
                 3.00    2.96 |  6.00   13.32 |  9.00    2.59 |

--------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0001)|   Area    (ha)=  38.80   Curve Number (CN)  = 88.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   1.08

     Ia as  0.2xS     (mm)=   6.927
     Unit Hyd Qpeak  (cms)=   1.981

     PEAK FLOW       (cms)=   2.097 (i)
     TIME TO PEAK    (hrs)=   6.750
     RUNOFF VOLUME    (mm)=  43.827
     TOTAL RAINFALL   (mm)=  73.537
     RUNOFF COEFFICIENT   =   0.596

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0002)|   Area    (ha)= 145.40   Curve Number (CN)  = 88.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   1.45

     Ia as  0.2xS     (mm)=   6.927
     Unit Hyd Qpeak  (cms)=   5.529

     PEAK FLOW       (cms)=   6.330 (i)
     TIME TO PEAK    (hrs)=   7.000
     RUNOFF VOLUME    (mm)=  43.824
     TOTAL RAINFALL   (mm)=  73.537
     RUNOFF COEFFICIENT   =   0.596

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0005)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
```

```
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0001):    38.80   2.097     6.75    43.83
      + ID2= 2 (  0002):   145.40   6.330     7.00    43.82
        ====================================================
        ID = 3 (  0005):   184.20   8.201     7.00    43.82

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.

-------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0003)|   Area    (ha)=   7.80   Curve Number (CN)  = 91.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   0.93

     Ia as  0.2xS     (mm)=   5.024
     Unit Hyd Qpeak  (cms)=   0.462

     PEAK FLOW       (cms)=   0.548 (i)
     TIME TO PEAK    (hrs)=   6.500
     RUNOFF VOLUME    (mm)=  50.142
     TOTAL RAINFALL   (mm)=  73.537
     RUNOFF COEFFICIENT   =   0.682

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

-------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0009)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0003):     7.80   0.548     6.50    50.14
      + ID2= 2 (  0005):   184.20   8.201     7.00    43.82
        ====================================================
        ID = 3 (  0009):   192.00   8.593     7.00    44.08

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.

-------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0004)|   Area    (ha)=   4.40   Curve Number (CN)  = 89.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   0.57

     Ia as  0.2xS     (mm)=   6.279
     Unit Hyd Qpeak  (cms)=   0.426

     PEAK FLOW       (cms)=   0.396 (i)
     TIME TO PEAK    (hrs)=   6.000
     RUNOFF VOLUME    (mm)=  45.985
     TOTAL RAINFALL   (mm)=  73.537
     RUNOFF COEFFICIENT   =   0.625

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

-------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0010)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0004):     4.40   0.396     6.00    45.99
      + ID2= 2 (  0009):   192.00   8.593     7.00    44.08
        ====================================================
        ID = 3 (  0010):   196.40   8.692     7.00    44.12

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.

-------------------------------------------------------------------------------
****************************
** SIMULATION NUMBER:   4 **
****************************
--------------------
| MASS STORM       |    Filename: C:\Users\eduva\AppD
|                  |              ata\Local\Temp\
|                  |              d05c0a7a-48aa-45ee-bba7-1e0c56c8fd51\71a8aabf
| Ptotal= 88.40 mm |    Comments: SCS type 2 mass curve
--------------------
                        Duration of storm    = 11.75 hrs
                        Mass curve time step = 15.00 min

                 TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                  hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
                 0.25    2.21 |  3.25    3.54 |  6.25   15.91 |  9.25    3.09
```

```
                 0.50    2.21 |  3.50    3.54 |  6.50    7.07 |  9.50    3.09
                 0.75    2.21 |  3.75    3.54 |  6.75    7.07 |  9.75    3.09
                 1.00    2.21 |  4.00    5.30 |  7.00    5.30 | 10.00    1.77
                 1.25    2.21 |  4.25    5.30 |  7.25    5.30 | 10.25    1.77
                 1.50    2.21 |  4.50    7.07 |  7.50    5.30 | 10.50    1.77
                 1.75    2.21 |  4.75    7.07 |  7.75    5.30 | 10.75    1.77
                 2.00    2.65 |  5.00   10.61 |  8.00    3.09 | 11.00    1.77
                 2.25    2.65 |  5.25   10.61 |  8.25    3.09 | 11.25    1.77
                 2.50    2.65 |  5.50   42.43 |  8.50    3.09 | 11.50    1.77
                 2.75    2.65 |  5.75  116.69 |  8.75    3.09 | 11.75    1.77
                 3.00    3.54 |  6.00   15.91 |  9.00    3.09 |

--------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0001)|   Area    (ha)=  38.80   Curve Number (CN)  = 88.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   1.08

     Ia as  0.2xS     (mm)=   6.927
     Unit Hyd Qpeak  (cms)=   1.981

     PEAK FLOW       (cms)=   2.713 (i)
     TIME TO PEAK    (hrs)=   6.750
     RUNOFF VOLUME    (mm)=  56.671
     TOTAL RAINFALL   (mm)=  87.847
     RUNOFF COEFFICIENT   =   0.645

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0002)|   Area    (ha)= 145.40   Curve Number (CN)  = 88.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   1.45

     Ia as  0.2xS     (mm)=   6.927
     Unit Hyd Qpeak  (cms)=   5.529

     PEAK FLOW       (cms)=   8.226 (i)
     TIME TO PEAK    (hrs)=   7.000
     RUNOFF VOLUME    (mm)=  56.666
     TOTAL RAINFALL   (mm)=  87.847
     RUNOFF COEFFICIENT   =   0.645

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------


--------------------
| ADD HYD  (  0005)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0001):    38.80   2.713     6.75    56.67
      + ID2= 2 (  0002):   145.40   8.226     7.00    56.67
        ====================================================
        ID = 3 (  0005):   184.20  10.634     7.00    56.67

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.

--------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0003)|   Area    (ha)=   7.80   Curve Number (CN)  = 91.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   0.93

     Ia as  0.2xS     (mm)=   5.024
     Unit Hyd Qpeak  (cms)=   0.462

     PEAK FLOW       (cms)=   0.692 (i)
     TIME TO PEAK    (hrs)=   6.500
     RUNOFF VOLUME    (mm)=  63.562
     TOTAL RAINFALL   (mm)=  87.847
     RUNOFF COEFFICIENT   =   0.724

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------


--------------------
| ADD HYD  (  0009)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0003):     7.80   0.692     6.50    63.56
      + ID2= 2 (  0005):   184.20  10.634     7.00    56.67
```

```
        ====================================================
        ID = 3 (  0009):   192.00  11.125     7.00    56.95

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.

-------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0004)|   Area    (ha)=   4.40   Curve Number (CN)  = 89.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   0.57

     Ia as  0.2xS     (mm)=   6.279
     Unit Hyd Qpeak  (cms)=   0.426

     PEAK FLOW       (cms)=   0.510 (i)
     TIME TO PEAK    (hrs)=   6.000
     RUNOFF VOLUME    (mm)=  59.066
     TOTAL RAINFALL   (mm)=  87.847
     RUNOFF COEFFICIENT   =   0.672

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

-------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0010)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0004):     4.40   0.510     6.00    59.07
      + ID2= 2 (  0009):   192.00  11.125     7.00    56.95
        ====================================================
        ID = 3 (  0010):   196.40  11.270     6.75    56.99

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.

-------------------------------------------------------------------------------
****************************
** SIMULATION NUMBER:   5 **
****************************
--------------------
| MASS STORM       |    Filename: C:\Users\eduva\AppD
|                  |              ata\Local\Temp\
|                  |              d05c0a7a-48aa-45ee-bba7-1e0c56c8fd51\5fad36d4
| Ptotal= 99.20 mm |    Comments: SCS type 2 mass curve
--------------------
                        Duration of storm    = 11.75 hrs
                        Mass curve time step = 15.00 min

                 TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                  hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
                 0.25    2.48 |  3.25    3.97 |  6.25   17.86 |  9.25    3.47
                 0.50    2.48 |  3.50    3.97 |  6.50    7.94 |  9.50    3.47
                 0.75    2.48 |  3.75    3.97 |  6.75    7.94 |  9.75    3.47
                 1.00    2.48 |  4.00    5.95 |  7.00    5.95 | 10.00    1.98
                 1.25    2.48 |  4.25    5.95 |  7.25    5.95 | 10.25    1.98
                 1.50    2.48 |  4.50    7.94 |  7.50    5.95 | 10.50    1.98
                 1.75    2.48 |  4.75    7.94 |  7.75    5.95 | 10.75    1.98
                 2.00    2.98 |  5.00   11.90 |  8.00    3.47 | 11.00    1.98
                 2.25    2.98 |  5.25   11.90 |  8.25    3.47 | 11.25    1.98
                 2.50    2.98 |  5.50   47.62 |  8.50    3.47 | 11.50    1.98
                 2.75    2.98 |  5.75  130.94 |  8.75    3.47 | 11.75    1.98
                 3.00    3.97 |  6.00   17.86 |  9.00    3.47 |

-------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0001)|   Area    (ha)=  38.80   Curve Number (CN)  = 88.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   1.08

     Ia as  0.2xS     (mm)=   6.927
     Unit Hyd Qpeak  (cms)=   1.981

     PEAK FLOW       (cms)=   3.180 (i)
     TIME TO PEAK    (hrs)=   6.750
     RUNOFF VOLUME    (mm)=  66.522
     TOTAL RAINFALL   (mm)=  98.580
     RUNOFF COEFFICIENT   =   0.675

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

-------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0002)|   Area    (ha)= 145.40   Curve Number (CN)  = 88.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
```

```
--------------------   U.H. Tp(hrs)=   1.45

     Ia as  0.2xS     (mm)=   6.927
     Unit Hyd Qpeak  (cms)=   5.529

     PEAK FLOW       (cms)=   9.672 (i)
     TIME TO PEAK    (hrs)=   7.000
     RUNOFF VOLUME    (mm)=  66.517
     TOTAL RAINFALL   (mm)=  98.580
     RUNOFF COEFFICIENT   =   0.675

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

---------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0005)|
|   1 +  2 =  3    |          AREA    QPEAK    TPEAK     R.V.
--------------------          (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0001):     38.80   3.180     6.75    66.52
      + ID2= 2 (  0002):    145.40   9.672     7.00    66.52
        ===================================================
        ID = 3 (  0005):    184.20  12.486     7.00    66.52

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.

---------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0003)|   Area    (ha)=   7.80   Curve Number (CN)  = 91.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   0.93

     Ia as  0.2xS     (mm)=   5.024
     Unit Hyd Qpeak  (cms)=   0.462

     PEAK FLOW       (cms)=   0.801 (i)
     TIME TO PEAK    (hrs)=   6.500
     RUNOFF VOLUME    (mm)=  73.768
     TOTAL RAINFALL   (mm)=  98.580
     RUNOFF COEFFICIENT   =   0.748

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

---------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0009)|
|   1 +  2 =  3    |          AREA    QPEAK    TPEAK     R.V.
--------------------          (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0003):      7.80   0.801     6.50    73.77
      + ID2= 2 (  0005):    184.20  12.486     7.00    66.52
        ===================================================
        ID = 3 (  0009):    192.00  13.051     7.00    66.81

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.

---------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0004)|   Area    (ha)=   4.40   Curve Number (CN)  = 89.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   0.57

     Ia as  0.2xS     (mm)=   6.279
     Unit Hyd Qpeak  (cms)=   0.426

     PEAK FLOW       (cms)=   0.597 (i)
     TIME TO PEAK    (hrs)=   6.000
     RUNOFF VOLUME    (mm)=  69.070
     TOTAL RAINFALL   (mm)=  98.580
     RUNOFF COEFFICIENT   =   0.701

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

---------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0010)|
|   1 +  2 =  3    |          AREA    QPEAK    TPEAK     R.V.
--------------------          (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0004):      4.40   0.597     6.00    69.07
      + ID2= 2 (  0009):    192.00  13.051     7.00    66.81
        ===================================================
        ID = 3 (  0010):    196.40  13.256     6.75    66.86
```

```
     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.

--------------------------------------------------------------------------------
***************************
** SIMULATION NUMBER:   6 **
***************************
--------------------
| MASS STORM       |    Filename: C:\Users\eduva\AppD
|                  |              ata\Local\Temp\
|                  |              d05c0a7a-48aa-45ee-bba7-1e0c56c8fd51\02429c0d
| Ptotal=109.90 mm |    Comments: SCS type 2 mass curve
--------------------
                        Duration of storm    = 11.75 hrs
                        Mass curve time step = 15.00 min

                 TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                  hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
                 0.25    2.75 |  3.25    4.40 |  6.25   19.78 |  9.25    3.85
                 0.50    2.75 |  3.50    4.40 |  6.50    8.79 |  9.50    3.85
                 0.75    2.75 |  3.75    4.40 |  6.75    8.79 |  9.75    3.85
                 1.00    2.75 |  4.00    6.59 |  7.00    6.59 | 10.00    2.20
                 1.25    2.75 |  4.25    6.59 |  7.25    6.59 | 10.25    2.20
                 1.50    2.75 |  4.50    8.79 |  7.50    6.59 | 10.50    2.20
                 1.75    2.75 |  4.75    8.79 |  7.75    6.59 | 10.75    2.20
                 2.00    3.30 |  5.00   13.19 |  8.00    3.85 | 11.00    2.20
                 2.25    3.30 |  5.25   13.19 |  8.25    3.85 | 11.25    2.20
                 2.50    3.30 |  5.50   52.75 |  8.50    3.85 | 11.50    2.20
                 2.75    3.30 |  5.75  145.07 |  8.75    3.85 | 11.75    2.20
                 3.00    4.40 |  6.00   19.78 |  9.00    3.85 |

--------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0001)|   Area    (ha)=  38.80   Curve Number (CN)  = 88.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   1.08

     Ia as  0.2xS     (mm)=   6.927
     Unit Hyd Qpeak  (cms)=   1.981

     PEAK FLOW       (cms)=   3.651 (i)
     TIME TO PEAK    (hrs)=   6.500
     RUNOFF VOLUME    (mm)=  76.418
     TOTAL RAINFALL   (mm)= 109.213
     RUNOFF COEFFICIENT   =   0.700

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0002)|   Area    (ha)= 145.40   Curve Number (CN)  = 88.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   1.45

     Ia as  0.2xS     (mm)=   6.927
     Unit Hyd Qpeak  (cms)=   5.529

     PEAK FLOW       (cms)=  11.116 (i)
     TIME TO PEAK    (hrs)=   7.000
     RUNOFF VOLUME    (mm)=  76.412
     TOTAL RAINFALL   (mm)= 109.213
     RUNOFF COEFFICIENT   =   0.700

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0005)|
|   1 +  2 =  3    |          AREA    QPEAK    TPEAK     R.V.
--------------------          (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0001):    38.80   3.651     6.50    76.42
      + ID2= 2 (  0002):   145.40  11.116     7.00    76.41
        ==================================================
        ID = 3 (  0005):   184.20  14.335     7.00    76.41

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.

--------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0003)|   Area    (ha)=   7.80   Curve Number (CN)  = 91.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   0.93

     Ia as  0.2xS     (mm)=   5.024
```

```
     Unit Hyd Qpeak  (cms)=   0.462

     PEAK FLOW       (cms)=   0.909 (i)
     TIME TO PEAK    (hrs)=   6.500
     RUNOFF VOLUME    (mm)=  83.966
     TOTAL RAINFALL   (mm)= 109.213
     RUNOFF COEFFICIENT   =   0.769

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0009)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0003):     7.80   0.909     6.50    83.97
      + ID2= 2 (  0005):   184.20  14.335     7.00    76.41
        ===================================================
        ID = 3 (  0009):   192.00  14.984     6.75    76.72

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.

--------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0004)|   Area    (ha)=   4.40   Curve Number (CN)  = 89.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   0.57

     Ia as  0.2xS     (mm)=   6.279
     Unit Hyd Qpeak  (cms)=   0.426

     PEAK FLOW       (cms)=   0.683 (i)
     TIME TO PEAK    (hrs)=   6.000
     RUNOFF VOLUME    (mm)=  79.101
     TOTAL RAINFALL   (mm)= 109.213
     RUNOFF COEFFICIENT   =   0.724

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0010)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0004):     4.40   0.683     6.00    79.10
      + ID2= 2 (  0009):   192.00  14.984     6.75    76.72
        ===================================================
        ID = 3 (  0010):   196.40  15.242     6.75    76.77

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.

--------------------------------------------------------------------------------
****************************
** SIMULATION NUMBER:   7 **
****************************

--------------------
|    READ STORM    |    Filename: C:\Users\eduva\AppD
|                  |              ata\Local\Temp\
|                  |              d05c0a7a-48aa-45ee-bba7-1e0c56c8fd51\6852c5a8
| Ptotal=212.00 mm |    Comments: * REGIONAL DESIGN STORM
--------------------
                 TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                  hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
                 0.20    6.00 |  3.20   13.00 |  6.20   23.00 |  9.20   53.00
                 0.40    6.00 |  3.40   13.00 |  6.40   23.00 |  9.40   53.00
                 0.60    6.00 |  3.60   13.00 |  6.60   23.00 |  9.60   53.00
                 0.80    6.00 |  3.80   13.00 |  6.80   23.00 |  9.80   53.00
                 1.00    6.00 |  4.00   13.00 |  7.00   23.00 | 10.00   53.00
                 1.20    4.00 |  4.20   17.00 |  7.20   13.00 | 10.20   38.00
                 1.40    4.00 |  4.40   17.00 |  7.40   13.00 | 10.40   38.00
                 1.60    4.00 |  4.60   17.00 |  7.60   13.00 | 10.60   38.00
                 1.80    4.00 |  4.80   17.00 |  7.80   13.00 | 10.80   38.00
                 2.00    4.00 |  5.00   17.00 |  8.00   13.00 | 11.00   38.00
                 2.20    6.00 |  5.20   13.00 |  8.20   13.00 | 11.20   13.00
                 2.40    6.00 |  5.40   13.00 |  8.40   13.00 | 11.40   13.00
                 2.60    6.00 |  5.60   13.00 |  8.60   13.00 | 11.60   13.00
                 2.80    6.00 |  5.80   13.00 |  8.80   13.00 | 11.80   13.00
                 3.00    6.00 |  6.00   13.00 |  9.00   13.00 | 12.00   13.00

--------------------------------------------------------------------------------
```

```
--------------------
|DESIGN SCS(  0001)|   Area    (ha)=  38.80   Curve Number (CN)  = 88.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   1.08

         NOTE:  RAINFALL WAS TRANSFORMED TO  15.0 MIN. TIME STEP.


                               ---- TRANSFORMED HYETOGRAPH ----
                 TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                  hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
                0.250    6.00 | 3.250   13.00 | 6.250   23.00 |  9.25   53.00
                0.500    6.00 | 3.500   13.00 | 6.500   23.00 |  9.50   53.00
                0.750    6.00 | 3.750   13.00 | 6.750   23.00 |  9.75   53.00
                1.000    6.00 | 4.000   13.00 | 7.000   23.00 | 10.00   53.00
                1.250    4.00 | 4.250   17.00 | 7.250   13.00 | 10.25   38.00
                1.500    4.00 | 4.500   17.00 | 7.500   13.00 | 10.50   38.00
                1.750    4.00 | 4.750   17.00 | 7.750   13.00 | 10.75   38.00
                2.000    4.00 | 5.000   17.00 | 8.000   13.00 | 11.00   38.00
                2.250    6.00 | 5.250   13.00 | 8.250   13.00 | 11.25   13.00
                2.500    6.00 | 5.500   13.00 | 8.500   13.00 | 11.50   13.00
                2.750    6.00 | 5.750   13.00 | 8.750   13.00 | 11.75   13.00
                3.000    6.00 | 6.000   13.00 | 9.000   13.00 | 12.00   13.00

     Ia as  0.2xS     (mm)=   6.927
     Unit Hyd Qpeak  (cms)=   1.981

     PEAK FLOW       (cms)=   4.419 (i)
     TIME TO PEAK    (hrs)=  11.000
     RUNOFF VOLUME    (mm)= 175.457
     TOTAL RAINFALL   (mm)= 212.000
     RUNOFF COEFFICIENT   =   0.828

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

-------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0002)|   Area    (ha)= 145.40   Curve Number (CN)  = 88.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   1.45

     Ia as  0.2xS     (mm)=   6.927
     Unit Hyd Qpeak  (cms)=   5.529

     PEAK FLOW       (cms)=  15.237 (i)
     TIME TO PEAK    (hrs)=  11.500
     RUNOFF VOLUME    (mm)= 175.444
     TOTAL RAINFALL   (mm)= 212.000
     RUNOFF COEFFICIENT   =   0.828

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

-------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0005)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0001):    38.80   4.419    11.00   175.46
      + ID2= 2 (  0002):   145.40  15.237    11.50   175.44
        ====================================================
        ID = 3 (  0005):   184.20  19.534    11.25   175.45

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.

-------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0003)|   Area    (ha)=   7.80   Curve Number (CN)  = 91.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   0.93

     Ia as  0.2xS     (mm)=   5.024
     Unit Hyd Qpeak  (cms)=   0.462

     PEAK FLOW       (cms)=   0.938 (i)
     TIME TO PEAK    (hrs)=  10.750
     RUNOFF VOLUME    (mm)= 184.612
     TOTAL RAINFALL   (mm)= 212.000
     RUNOFF COEFFICIENT   =   0.871

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

-------------------------------------------------------------------------------
```

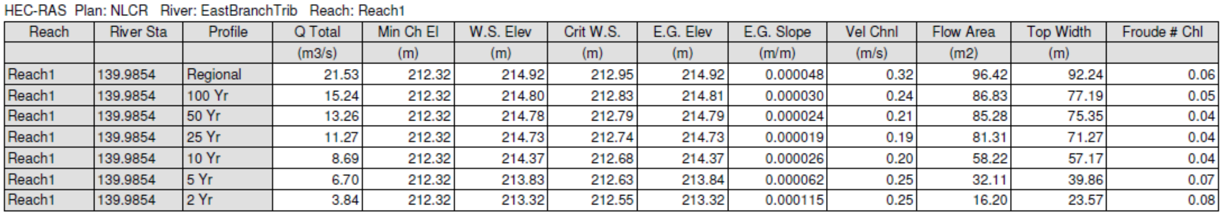
```
--------------------
| ADD HYD  (  0009)|
|   1 +  2 =  3    |          AREA    QPEAK    TPEAK     R.V.
--------------------          (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0003):      7.80   0.938    10.75   184.61
      + ID2= 2 (  0005):    184.20  19.534    11.25   175.45
        ====================================================
        ID = 3 (  0009):    192.00  20.403    11.25   175.82

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.

-------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0004)|   Area    (ha)=   4.40   Curve Number (CN)  = 89.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   0.57

     Ia as  0.2xS     (mm)=   6.279
     Unit Hyd Qpeak  (cms)=   0.426

     PEAK FLOW       (cms)=   0.589 (i)
     TIME TO PEAK    (hrs)=  10.250
     RUNOFF VOLUME    (mm)= 178.988
     TOTAL RAINFALL   (mm)= 212.000
     RUNOFF COEFFICIENT   =   0.844

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

-------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0010)|
|   1 +  2 =  3    |          AREA    QPEAK    TPEAK     R.V.
--------------------          (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0004):      4.40   0.589    10.25   178.99
      + ID2= 2 (  0009):    192.00  20.403    11.25   175.82
        ====================================================
        ID = 3 (  0010):    196.40  20.829    11.25   175.89

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.

-------------------------------------------------------------------------------
```

```
****************************
** SIMULATION NUMBER:   1 **
****************************

--------------------
|    READ STORM    |    Filename: C:\Users\eduva\AppD
|                  |              ata\Local\Temp\
|                  |              3e12f5f2-e86a-498e-8e87-b52cdf2f2351\6852c5a8
| Ptotal=212.00 mm |    Comments: * REGIONAL DESIGN STORM
--------------------
                 TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                  hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
                 0.20    6.00 |  3.20   13.00 |  6.20   23.00 |  9.20   53.00
                 0.40    6.00 |  3.40   13.00 |  6.40   23.00 |  9.40   53.00
                 0.60    6.00 |  3.60   13.00 |  6.60   23.00 |  9.60   53.00
                 0.80    6.00 |  3.80   13.00 |  6.80   23.00 |  9.80   53.00
                 1.00    6.00 |  4.00   13.00 |  7.00   23.00 | 10.00   53.00
                 1.20    4.00 |  4.20   17.00 |  7.20   13.00 | 10.20   38.00
                 1.40    4.00 |  4.40   17.00 |  7.40   13.00 | 10.40   38.00
                 1.60    4.00 |  4.60   17.00 |  7.60   13.00 | 10.60   38.00
                 1.80    4.00 |  4.80   17.00 |  7.80   13.00 | 10.80   38.00
                 2.00    4.00 |  5.00   17.00 |  8.00   13.00 | 11.00   38.00
                 2.20    6.00 |  5.20   13.00 |  8.20   13.00 | 11.20   13.00
                 2.40    6.00 |  5.40   13.00 |  8.40   13.00 | 11.40   13.00
                 2.60    6.00 |  5.60   13.00 |  8.60   13.00 | 11.60   13.00
                 2.80    6.00 |  5.80   13.00 |  8.80   13.00 | 11.80   13.00
                 3.00    6.00 |  6.00   13.00 |  9.00   13.00 | 12.00   13.00

-------------------------------------------------------------------------------

--------------------
|DESIGN SCS(  0001)|   Area    (ha)=  38.80   Curve Number (CN)  = 95.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   1.08

         NOTE:  RAINFALL WAS TRANSFORMED TO  15.0 MIN. TIME STEP.


                               ---- TRANSFORMED HYETOGRAPH ----
                 TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                  hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
                0.250    6.00 | 3.250   13.00 | 6.250   23.00 |  9.25   53.00
                0.500    6.00 | 3.500   13.00 | 6.500   23.00 |  9.50   53.00
                0.750    6.00 | 3.750   13.00 | 6.750   23.00 |  9.75   53.00
                1.000    6.00 | 4.000   13.00 | 7.000   23.00 | 10.00   53.00
                1.250    4.00 | 4.250   17.00 | 7.250   13.00 | 10.25   38.00
                1.500    4.00 | 4.500   17.00 | 7.500   13.00 | 10.50   38.00
                1.750    4.00 | 4.750   17.00 | 7.750   13.00 | 10.75   38.00
                2.000    4.00 | 5.000   17.00 | 8.000   13.00 | 11.00   38.00
                2.250    6.00 | 5.250   13.00 | 8.250   13.00 | 11.25   13.00
                2.500    6.00 | 5.500   13.00 | 8.500   13.00 | 11.50   13.00
                2.750    6.00 | 5.750   13.00 | 8.750   13.00 | 11.75   13.00
                3.000    6.00 | 6.000   13.00 | 9.000   13.00 | 12.00   13.00

     Ia as  0.2xS     (mm)=   2.674
     Unit Hyd Qpeak  (cms)=   1.981

     PEAK FLOW       (cms)=   4.568 (i)
     TIME TO PEAK    (hrs)=  11.000
     RUNOFF VOLUME    (mm)= 196.778
     TOTAL RAINFALL   (mm)= 212.000
     RUNOFF COEFFICIENT   =   0.928

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

-------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0002)|   Area    (ha)= 145.40   Curve Number (CN)  = 95.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   1.45

     Ia as  0.2xS     (mm)=   2.674
     Unit Hyd Qpeak  (cms)=   5.529

     PEAK FLOW       (cms)=  15.762 (i)
     TIME TO PEAK    (hrs)=  11.250
     RUNOFF VOLUME    (mm)= 196.764
     TOTAL RAINFALL   (mm)= 212.000
     RUNOFF COEFFICIENT   =   0.928

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

-------------------------------------------------------------------------------
```

```
--------------------
| ADD HYD  (  0005)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0001):    38.80   4.568    11.00   196.78
      + ID2= 2 (  0002):   145.40  15.762    11.25   196.76
        ====================================================
        ID = 3 (  0005):   184.20  20.218    11.25   196.77

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.

-------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0003)|   Area    (ha)=   7.80   Curve Number (CN)  = 96.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   0.93

     Ia as  0.2xS     (mm)=   2.117
     Unit Hyd Qpeak  (cms)=   0.462

     PEAK FLOW       (cms)=   0.956 (i)
     TIME TO PEAK    (hrs)=  10.750
     RUNOFF VOLUME    (mm)= 199.850
     TOTAL RAINFALL   (mm)= 212.000
     RUNOFF COEFFICIENT   =   0.943

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

-------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0009)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0003):     7.80   0.956    10.75   199.85
      + ID2= 2 (  0005):   184.20  20.218    11.25   196.77
        ====================================================
        ID = 3 (  0009):   192.00  21.101    11.25   196.89

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.

-------------------------------------------------------------------------------
--------------------
|DESIGN SCS(  0004)|   Area    (ha)=   4.40   Curve Number (CN)  = 95.0
|ID= 1 DT=15.0 min |   Ia      (mm)=  0.2 S   # of Linear Res.(N)= 5.00
--------------------   U.H. Tp(hrs)=   0.57

     Ia as  0.2xS     (mm)=   2.674
     Unit Hyd Qpeak  (cms)=   0.426

     PEAK FLOW       (cms)=   0.606 (i)
     TIME TO PEAK    (hrs)=  10.250
     RUNOFF VOLUME    (mm)= 197.316
     TOTAL RAINFALL   (mm)= 212.000
     RUNOFF COEFFICIENT   =   0.931

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

-------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0010)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0004):     4.40   0.606    10.25   197.32
      + ID2= 2 (  0009):   192.00  21.101    11.25   196.89
        ====================================================
        ID = 3 (  0010):   196.40  21.534    11.25   196.90

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.

-------------------------------------------------------------------------------
```

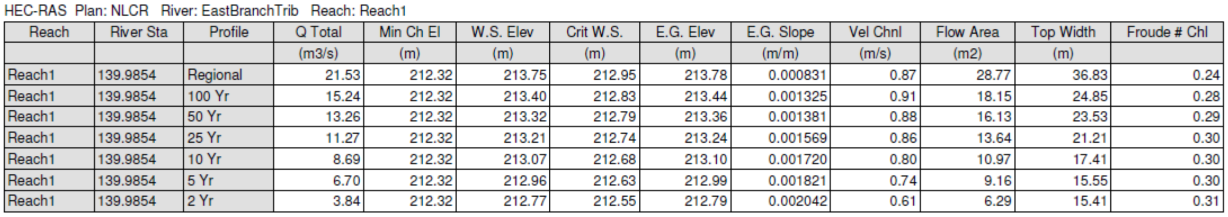
HEC-RAS Results at Upstream of Main Culvert
Multiple Culvert Size Scenarios
Road Deck Elevation = 214.68 masl

Culvert: 3m wide x 0.7 m high


HEC-RAS Plan: NLCR River: EastBranchTrib Reach: Reach1

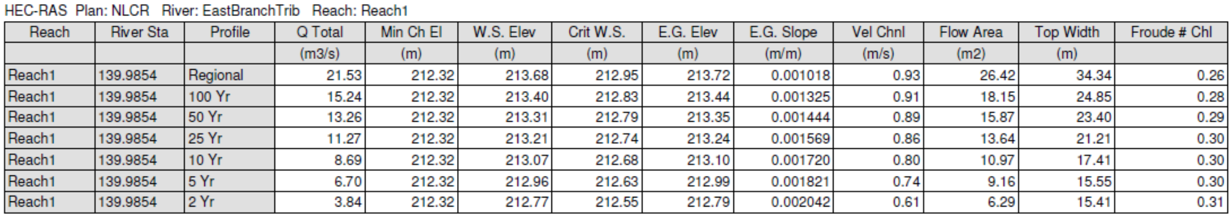
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Reach1	139.9854	Regional	21.53	212.32	214.92	212.95	214.92	0.000048	0.32	96.42	92.24	0.06
Reach1	139.9854	100 Yr	15.24	212.32	214.80	212.83	214.81	0.000030	0.24	86.83	77.19	0.05
Reach1	139.9854	50 Yr	13.26	212.32	214.78	212.79	214.79	0.000024	0.21	85.28	75.35	0.04
Reach1	139.9854	25 Yr	11.27	212.32	214.73	212.74	214.73	0.000019	0.19	81.31	71.27	0.04
Reach1	139.9854	10 Yr	8.69	212.32	214.37	212.68	214.37	0.000026	0.20	58.22	57.17	0.04
Reach1	139.9854	5 Yr	6.70	212.32	213.83	212.63	213.84	0.000062	0.25	32.11	39.86	0.07
Reach1	139.9854	2 Yr	3.84	212.32	213.32	212.55	213.32	0.000115	0.25	16.20	23.57	0.08

Culvert: 10m wide x 0.7 m high


HEC-RAS Plan: NLCR River: EastBranchTrib Reach: Reach1

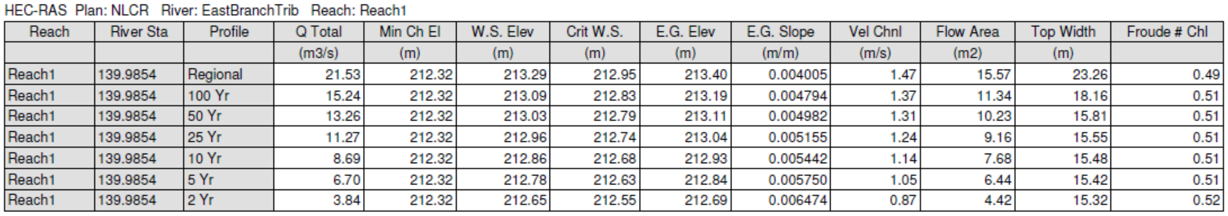
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Reach1	139.9854	Regional	21.53	212.32	213.75	212.95	213.78	0.000831	0.87	28.77	36.83	0.24
Reach1	139.9854	100 Yr	15.24	212.32	213.40	212.83	213.44	0.001325	0.91	18.15	24.85	0.28
Reach1	139.9854	50 Yr	13.26	212.32	213.32	212.79	213.36	0.001381	0.88	16.13	23.53	0.29
Reach1	139.9854	25 Yr	11.27	212.32	213.21	212.74	213.24	0.001569	0.86	13.64	21.21	0.30
Reach1	139.9854	10 Yr	8.69	212.32	213.07	212.68	213.10	0.001720	0.80	10.97	17.41	0.30
Reach1	139.9854	5 Yr	6.70	212.32	212.96	212.63	212.99	0.001821	0.74	9.16	15.55	0.30
Reach1	139.9854	2 Yr	3.84	212.32	212.77	212.55	212.79	0.002042	0.61	6.29	15.41	0.31

Culvert: 10m wide x 1.5 m high


HEC-RAS Plan: NLCR River: EastBranchTrib Reach: Reach1

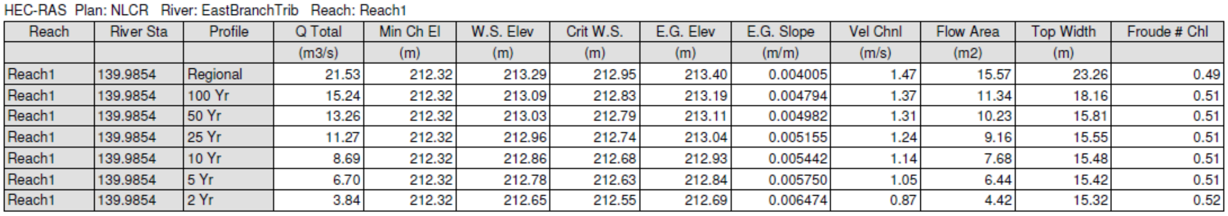
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Reach1	139.9854	Regional	21.53	212.32	213.68	212.95	213.72	0.001018	0.93	26.42	34.34	0.26
Reach1	139.9854	100 Yr	15.24	212.32	213.40	212.83	213.44	0.001325	0.91	18.15	24.85	0.28
Reach1	139.9854	50 Yr	13.26	212.32	213.31	212.79	213.35	0.001444	0.89	15.87	23.40	0.29
Reach1	139.9854	25 Yr	11.27	212.32	213.21	212.74	213.24	0.001569	0.86	13.64	21.21	0.30
Reach1	139.9854	10 Yr	8.69	212.32	213.07	212.68	213.10	0.001720	0.80	10.97	17.41	0.30
Reach1	139.9854	5 Yr	6.70	212.32	212.96	212.63	212.99	0.001821	0.74	9.16	15.55	0.30
Reach1	139.9854	2 Yr	3.84	212.32	212.77	212.55	212.79	0.002042	0.61	6.29	15.41	0.31

Culvert: 15m wide x 0.7 m high


HEC-RAS Plan: NLCR River: EastBranchTrib Reach: Reach1

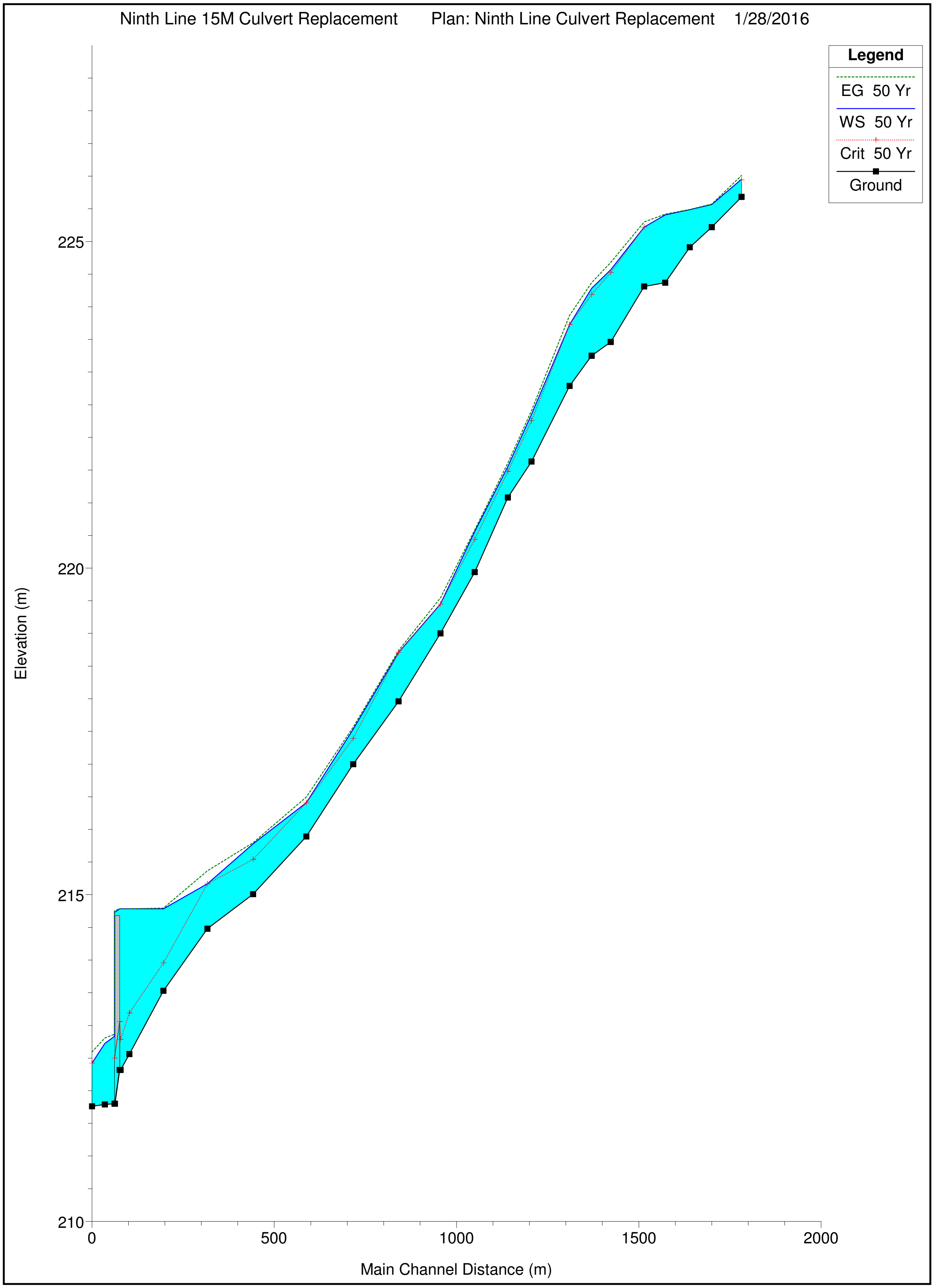
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Reach1	139.9854	Regional	21.53	212.32	213.29	212.95	213.40	0.004005	1.47	15.57	23.26	0.49
Reach1	139.9854	100 Yr	15.24	212.32	213.09	212.83	213.19	0.004794	1.37	11.34	18.16	0.51
Reach1	139.9854	50 Yr	13.26	212.32	213.03	212.79	213.11	0.004982	1.31	10.23	15.81	0.51
Reach1	139.9854	25 Yr	11.27	212.32	212.96	212.74	213.04	0.005155	1.24	9.16	15.55	0.51
Reach1	139.9854	10 Yr	8.69	212.32	212.86	212.68	212.93	0.005442	1.14	7.68	15.48	0.51
Reach1	139.9854	5 Yr	6.70	212.32	212.78	212.63	212.84	0.005750	1.05	6.44	15.42	0.51
Reach1	139.9854	2 Yr	3.84	212.32	212.65	212.55	212.69	0.006474	0.87	4.42	15.32	0.52

Culvert: 15m wide x 1.5 m high

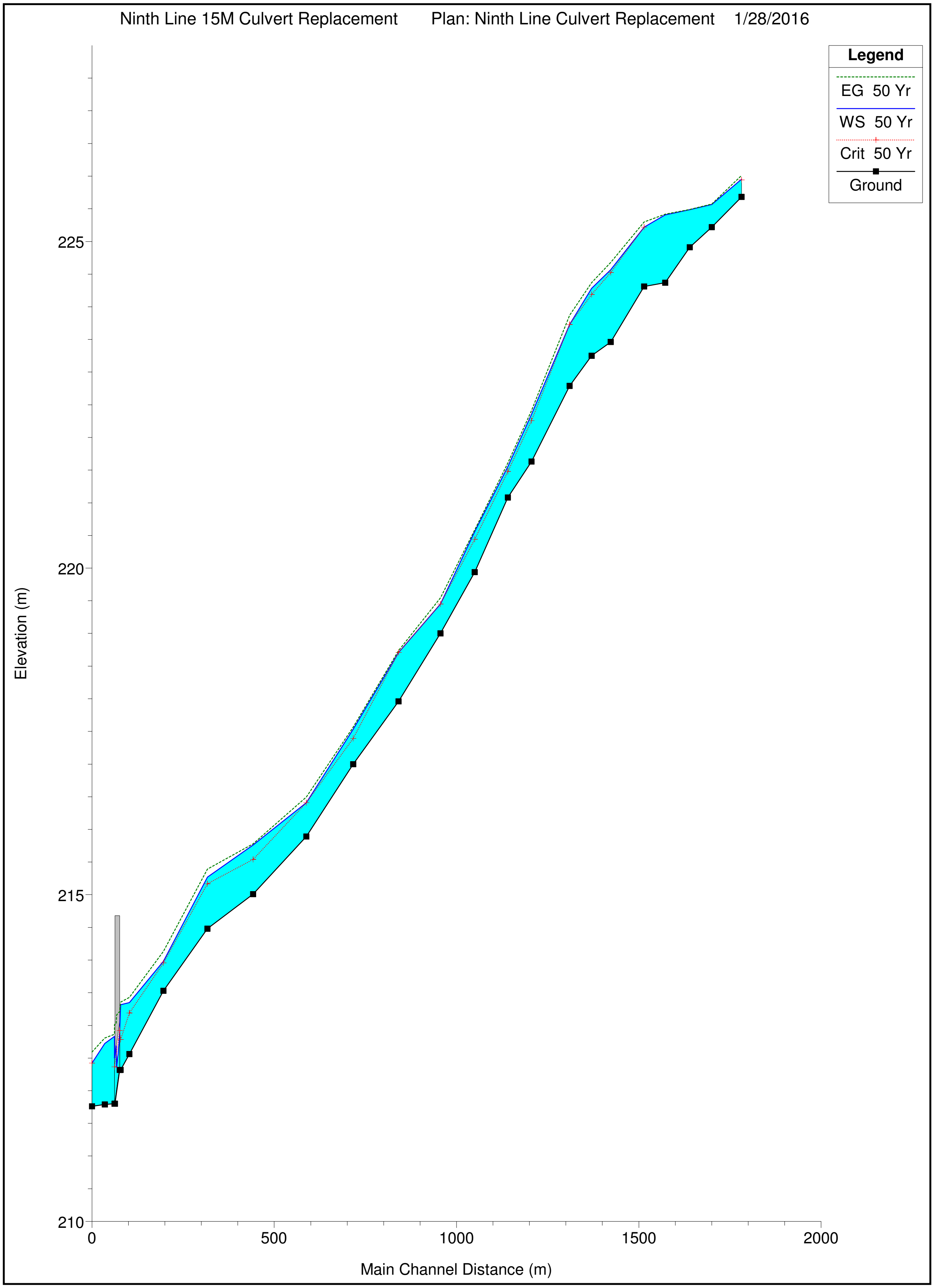

HEC-RAS Plan: NLCR River: EastBranchTrib Reach: Reach1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Reach1	139.9854	Regional	21.53	212.32	213.29	212.95	213.40	0.004005	1.47	15.57	23.26	0.49
Reach1	139.9854	100 Yr	15.24	212.32	213.09	212.83	213.19	0.004794	1.37	11.34	18.16	0.51
Reach1	139.9854	50 Yr	13.26	212.32	213.03	212.79	213.11	0.004982	1.31	10.23	15.81	0.51
Reach1	139.9854	25 Yr	11.27	212.32	212.96	212.74	213.04	0.005155	1.24	9.16	15.55	0.51
Reach1	139.9854	10 Yr	8.69	212.32	212.86	212.68	212.93	0.005442	1.14	7.68	15.48	0.51
Reach1	139.9854	5 Yr	6.70	212.32	212.78	212.63	212.84	0.005750	1.05	6.44	15.42	0.51
Reach1	139.9854	2 Yr	3.84	212.32	212.65	212.55	212.69	0.006474	0.87	4.42	15.32	0.52

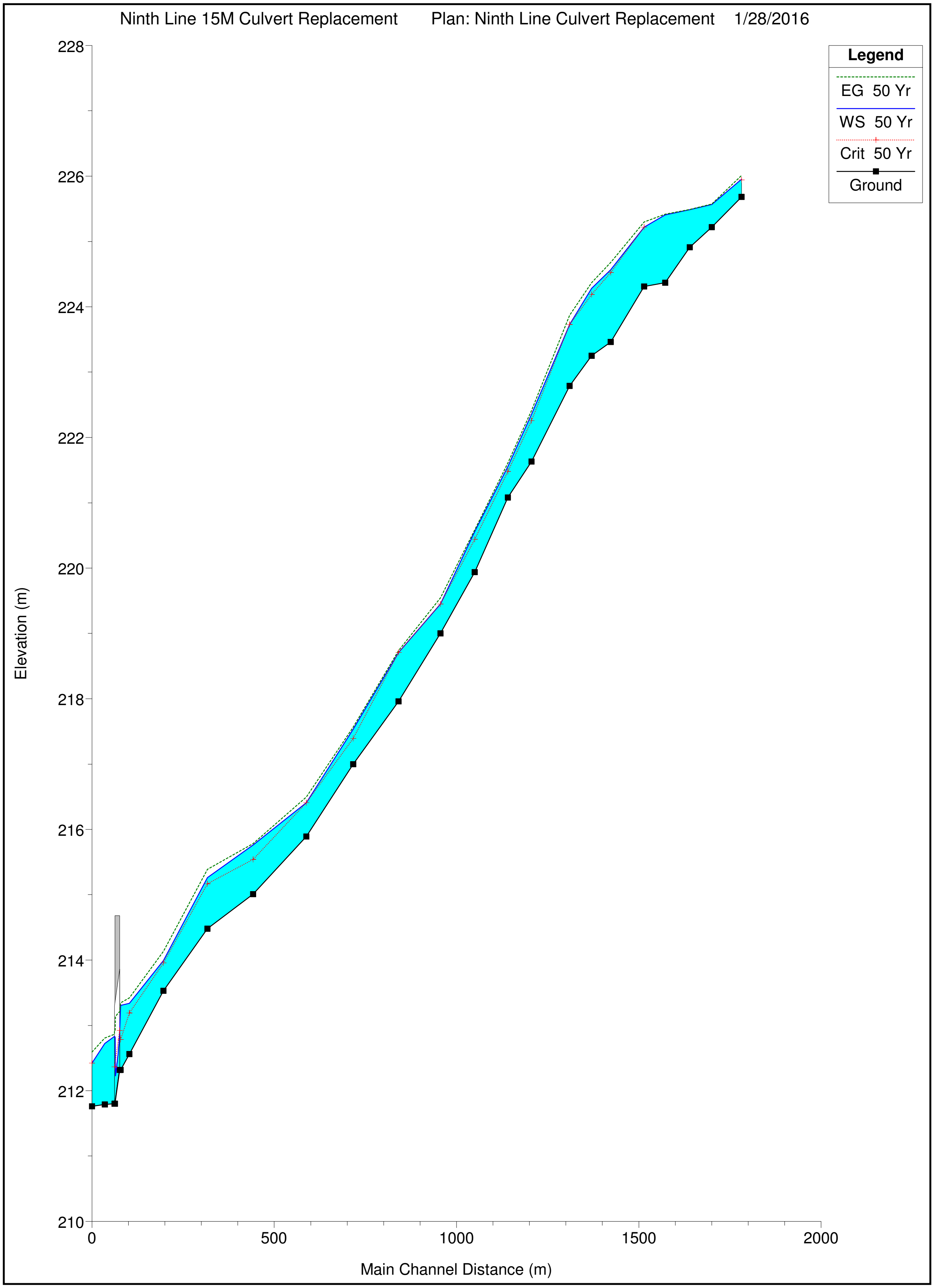
Culvert: 3m wide x 0.7m high
Flow: 50 year peak



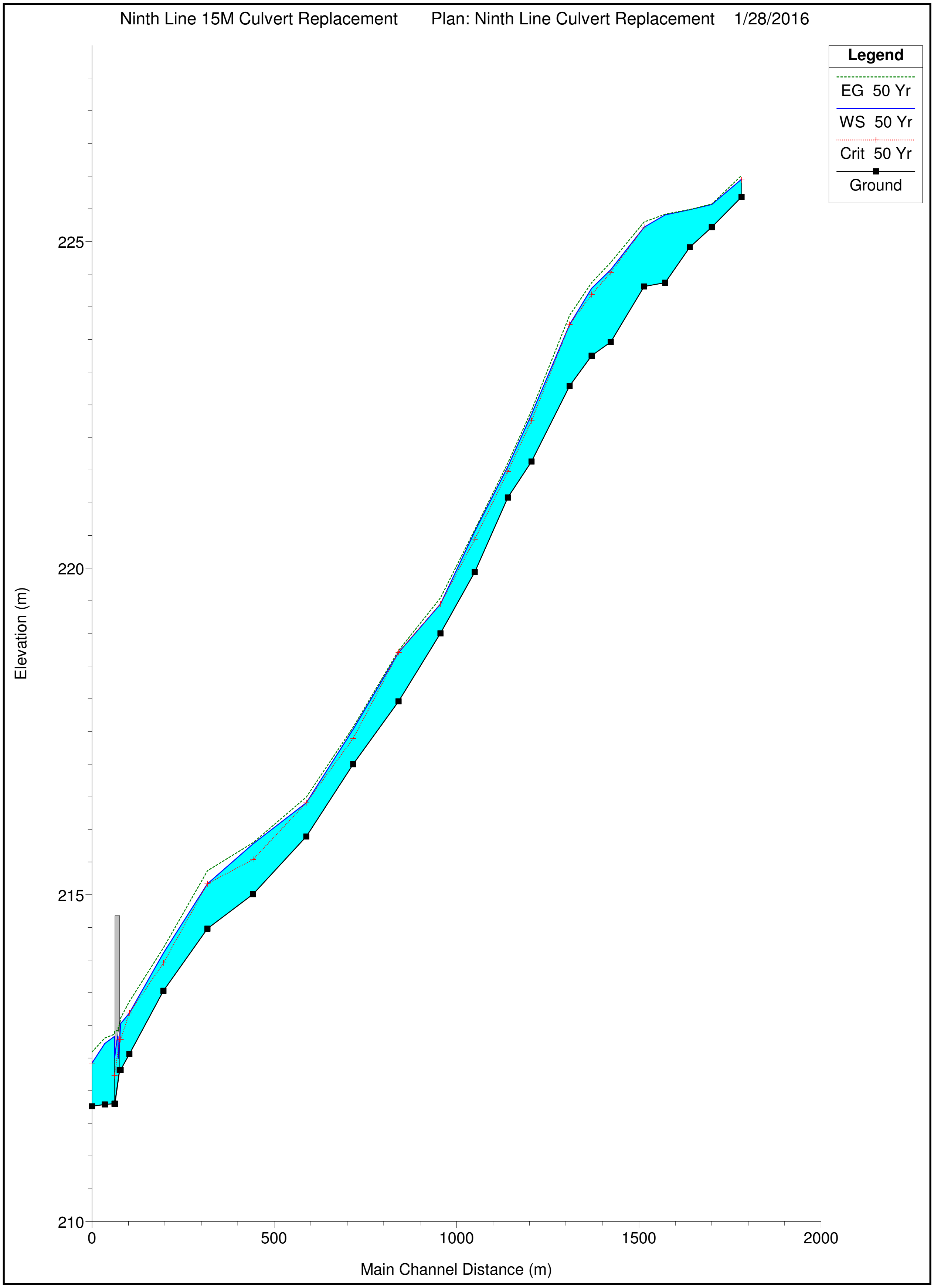
Culvert: 10m wide x 0.7 high
Flow: 50 year peak



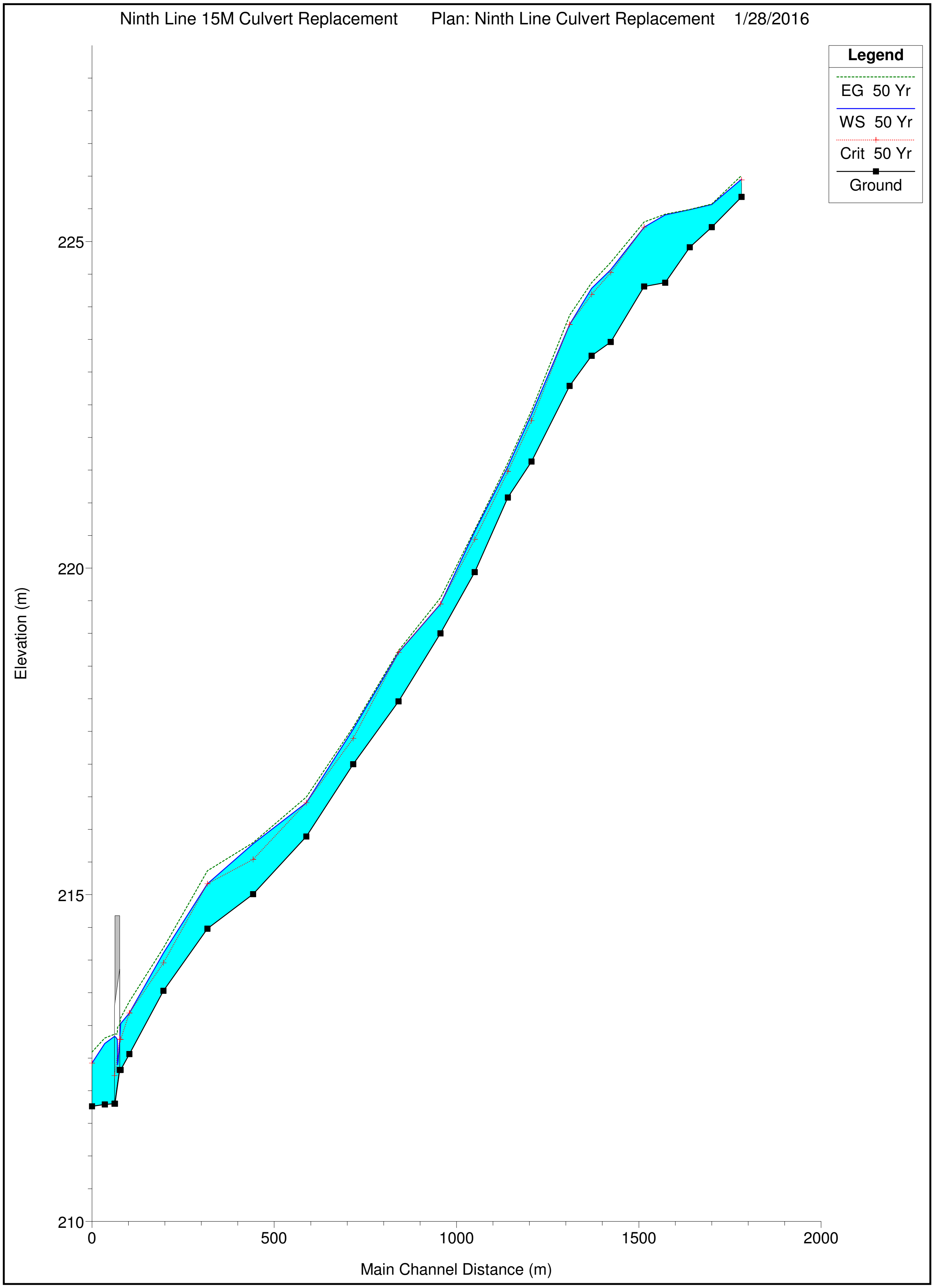
Culvert: 10m wide x 1.5m high
Flow: 50 year peak



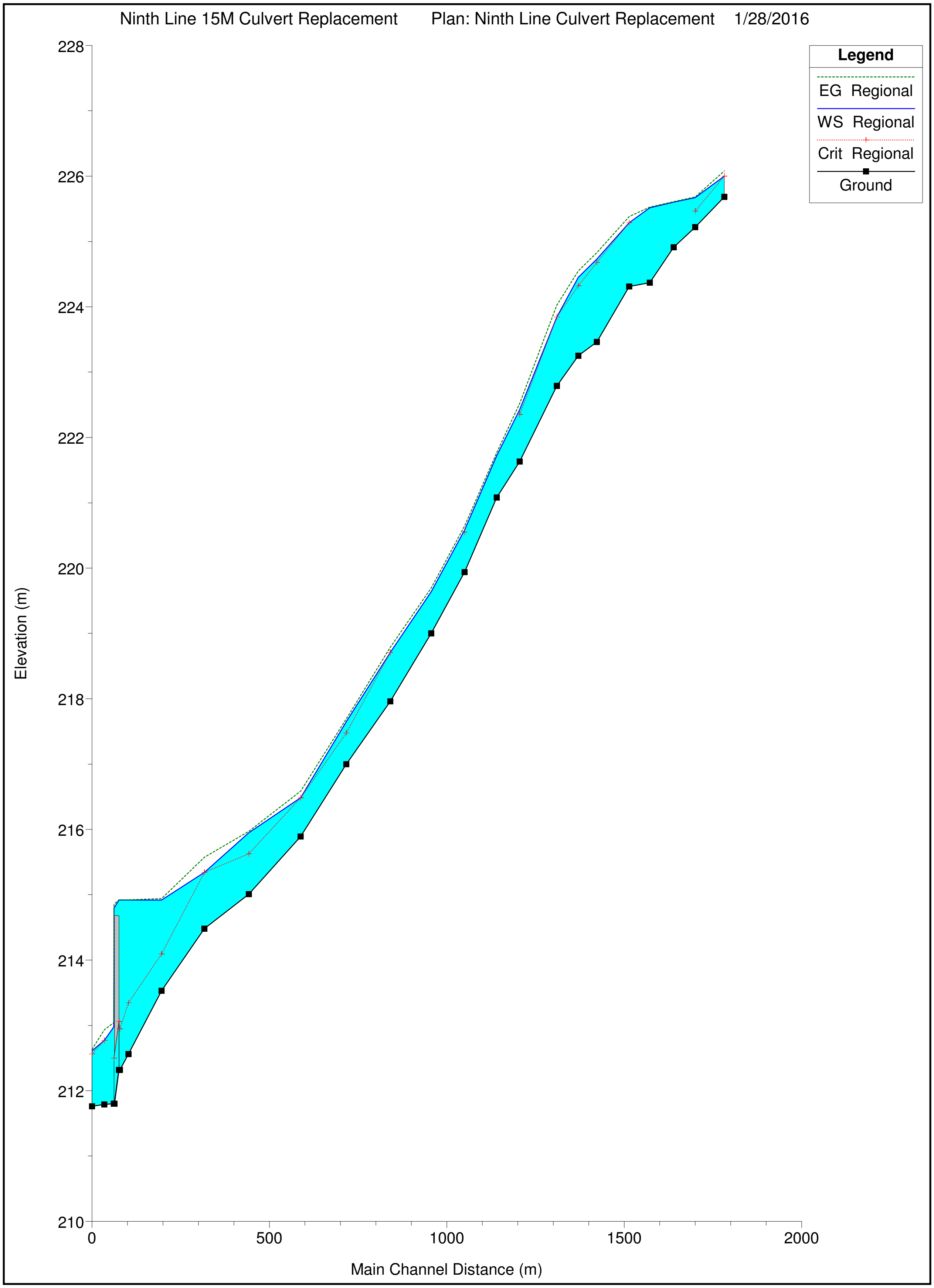
Culvert: 15m wide x 0.7m high
Flow: 50 year peak

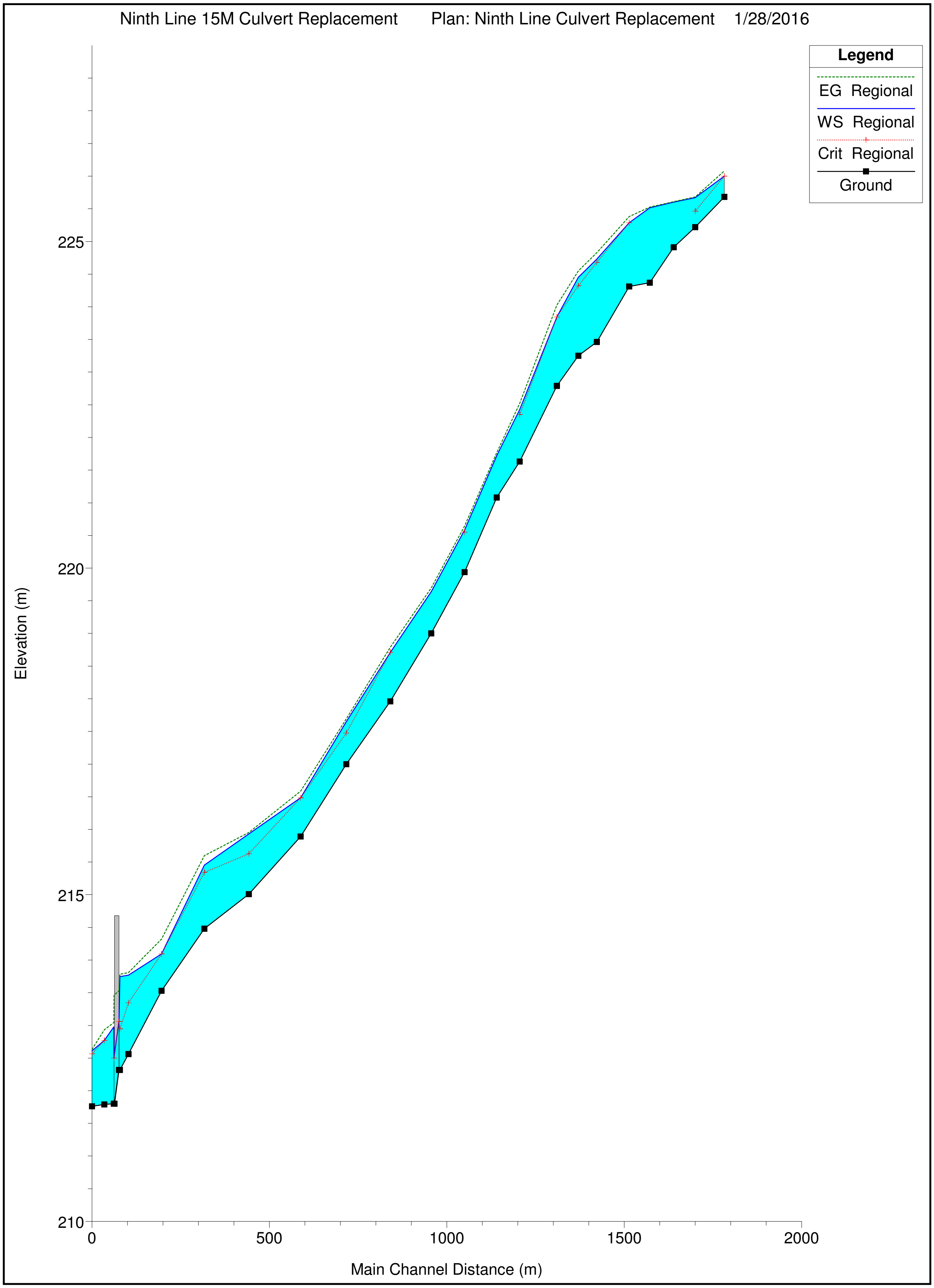


Culvert: 15m wide x 1.5m high
Flow: 50 year peak



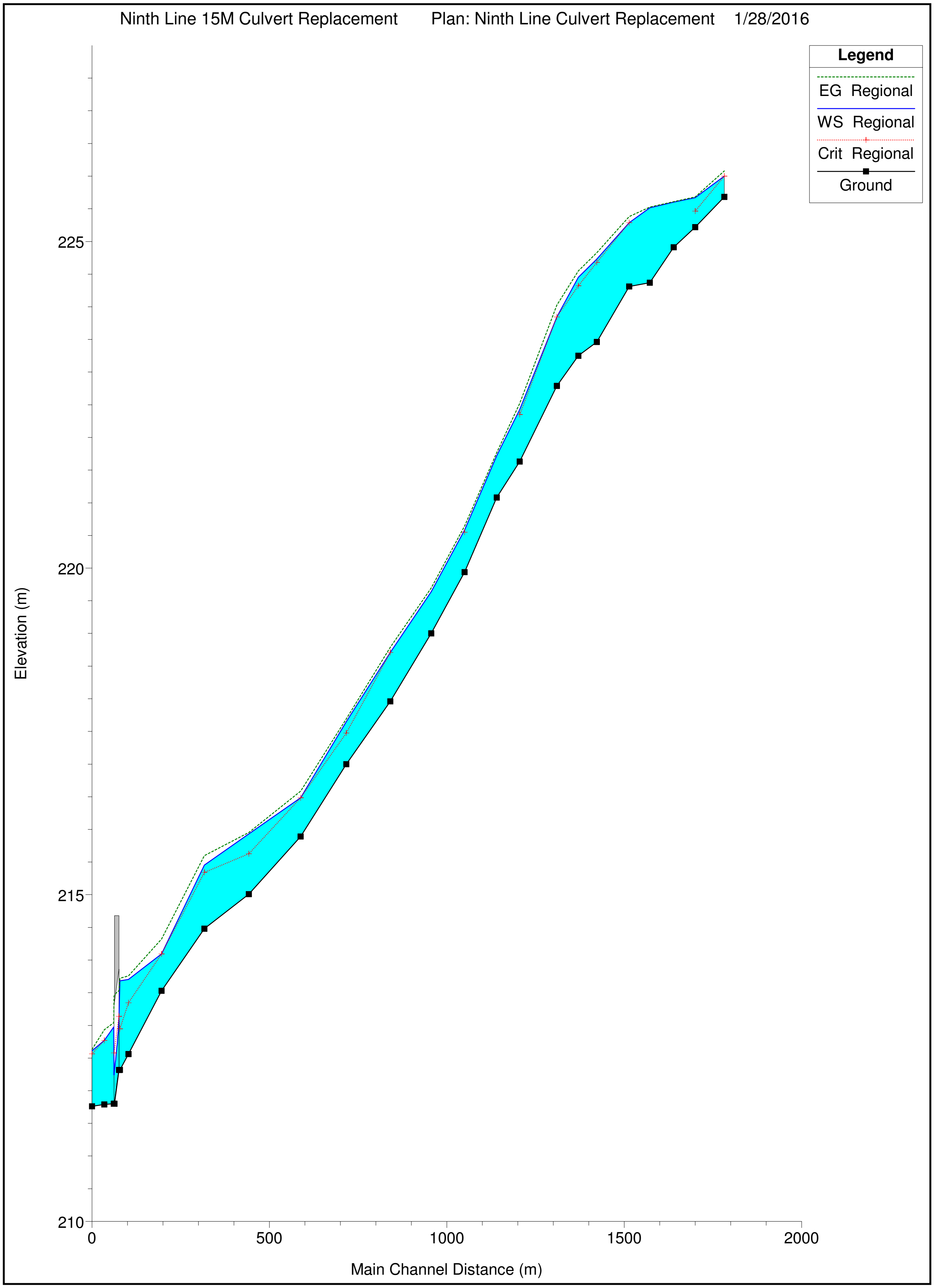
Culvert: 3m wide x 0.7m high
Flow: Regional Storm peak



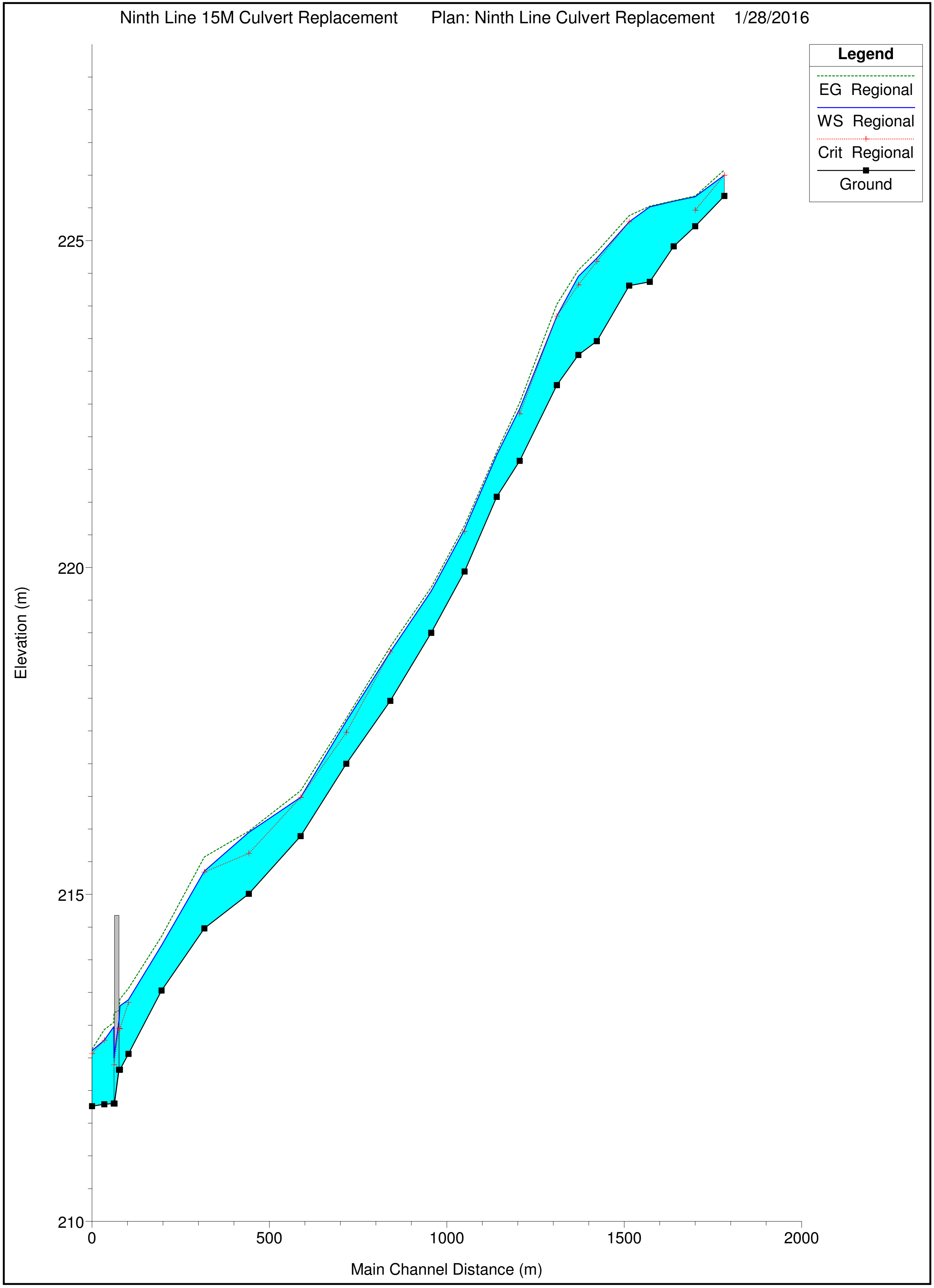


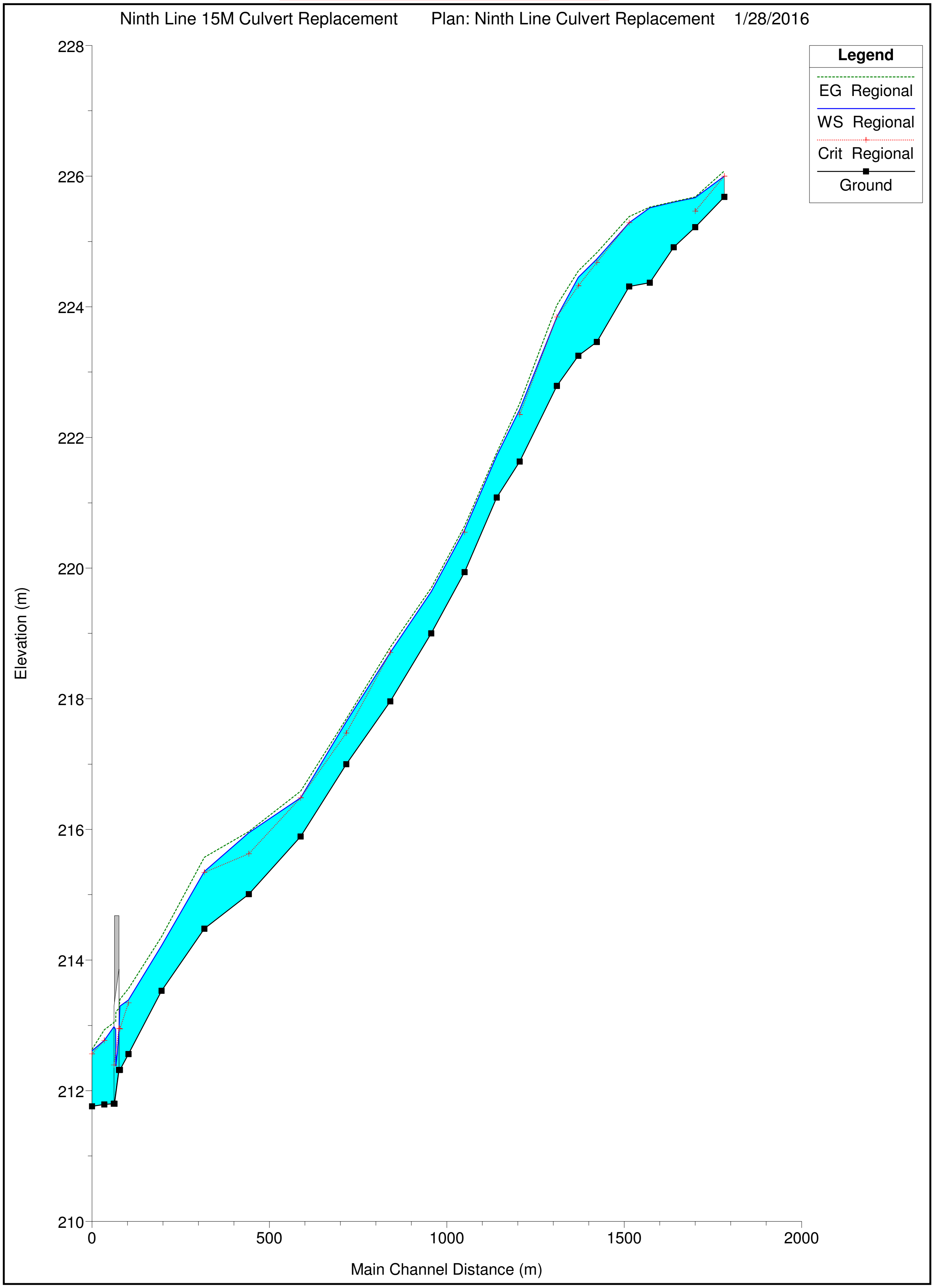
Culvert: 10m wide x 0.7m high
Flow: Regional Storm peak

Culvert: 10m wide x 1.5m high
Flow: Regional Storm peak

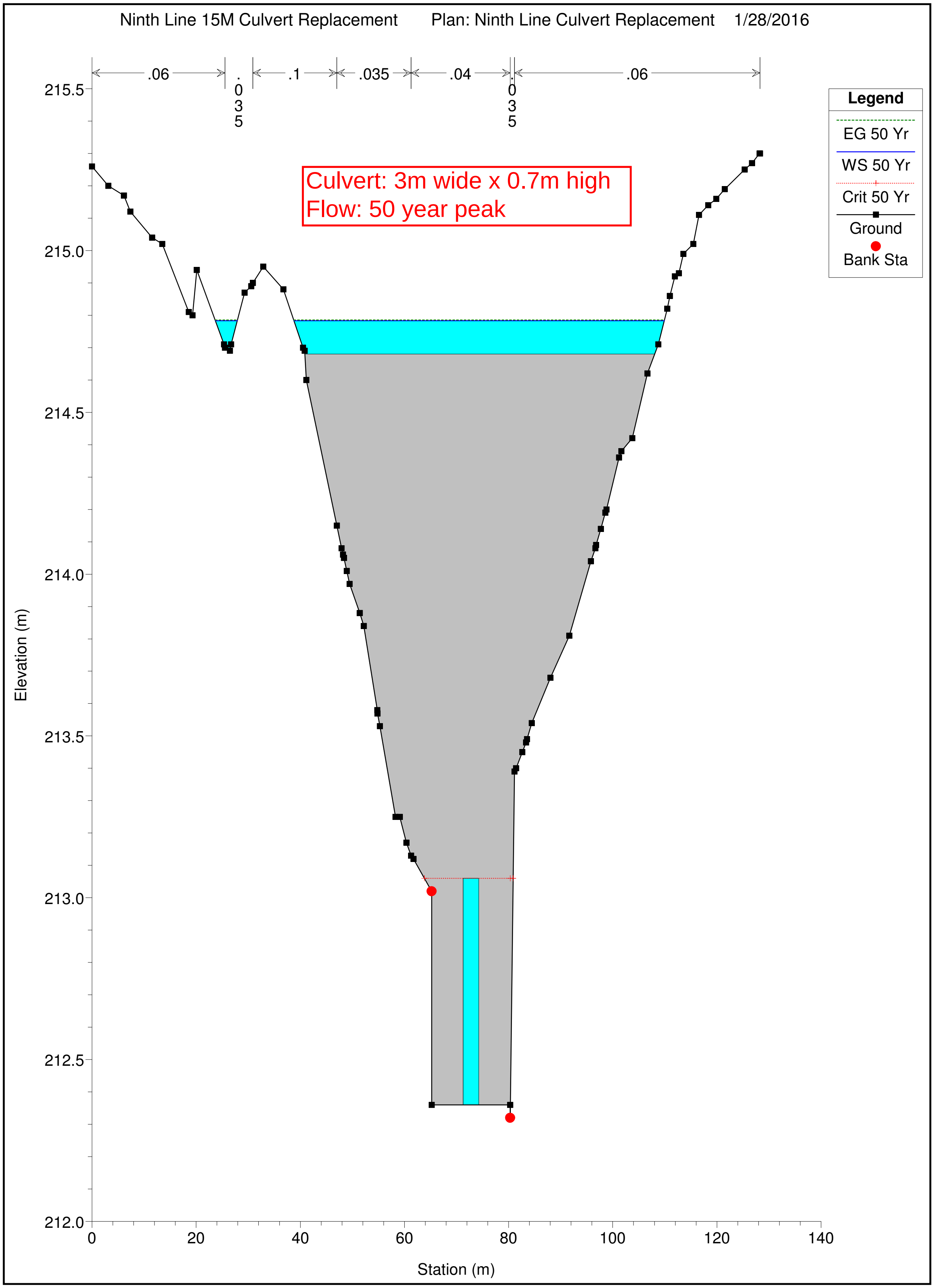


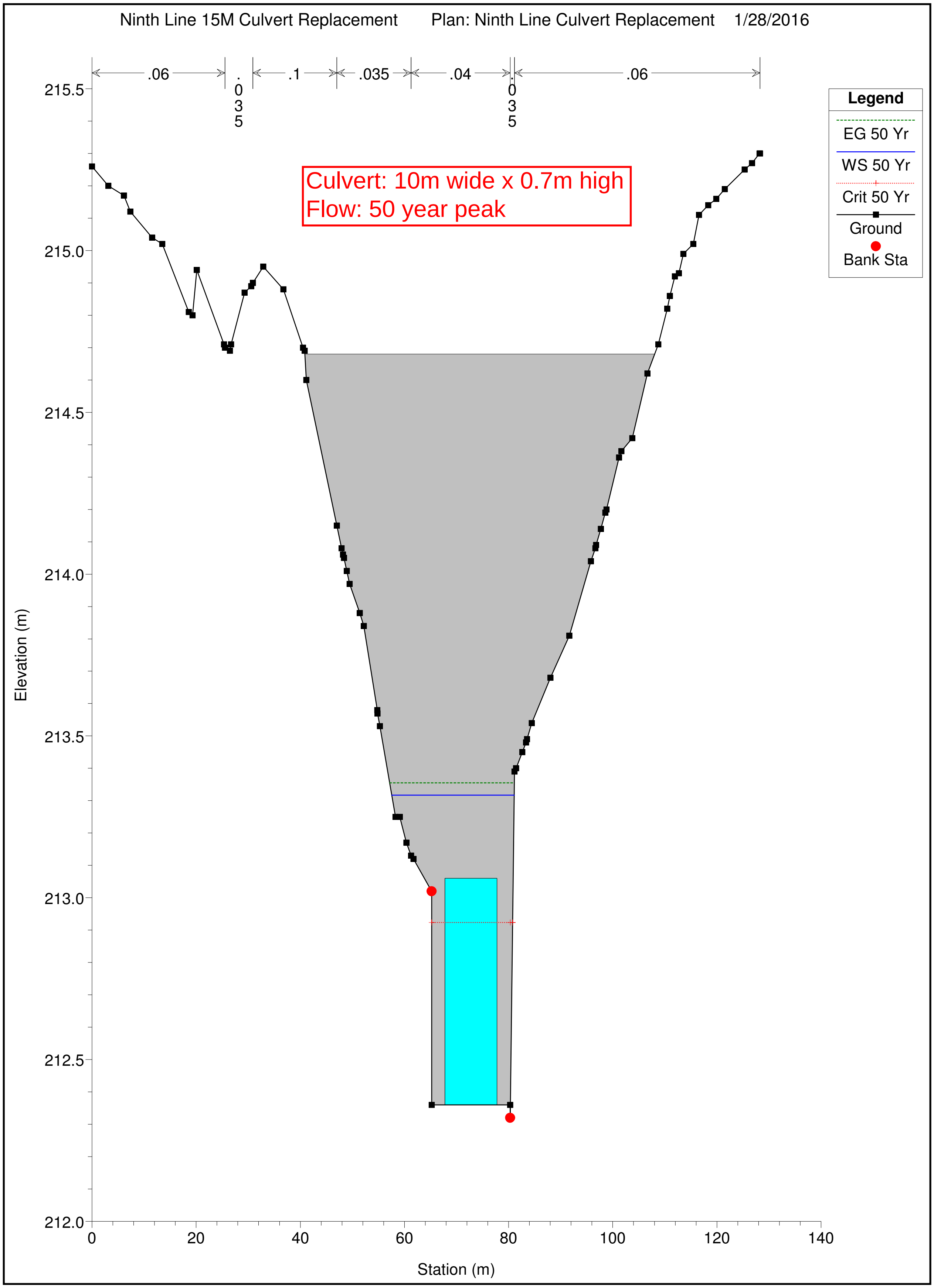
Culvert: 15m wide x 0.7m high
Flow: Regional Storm peak

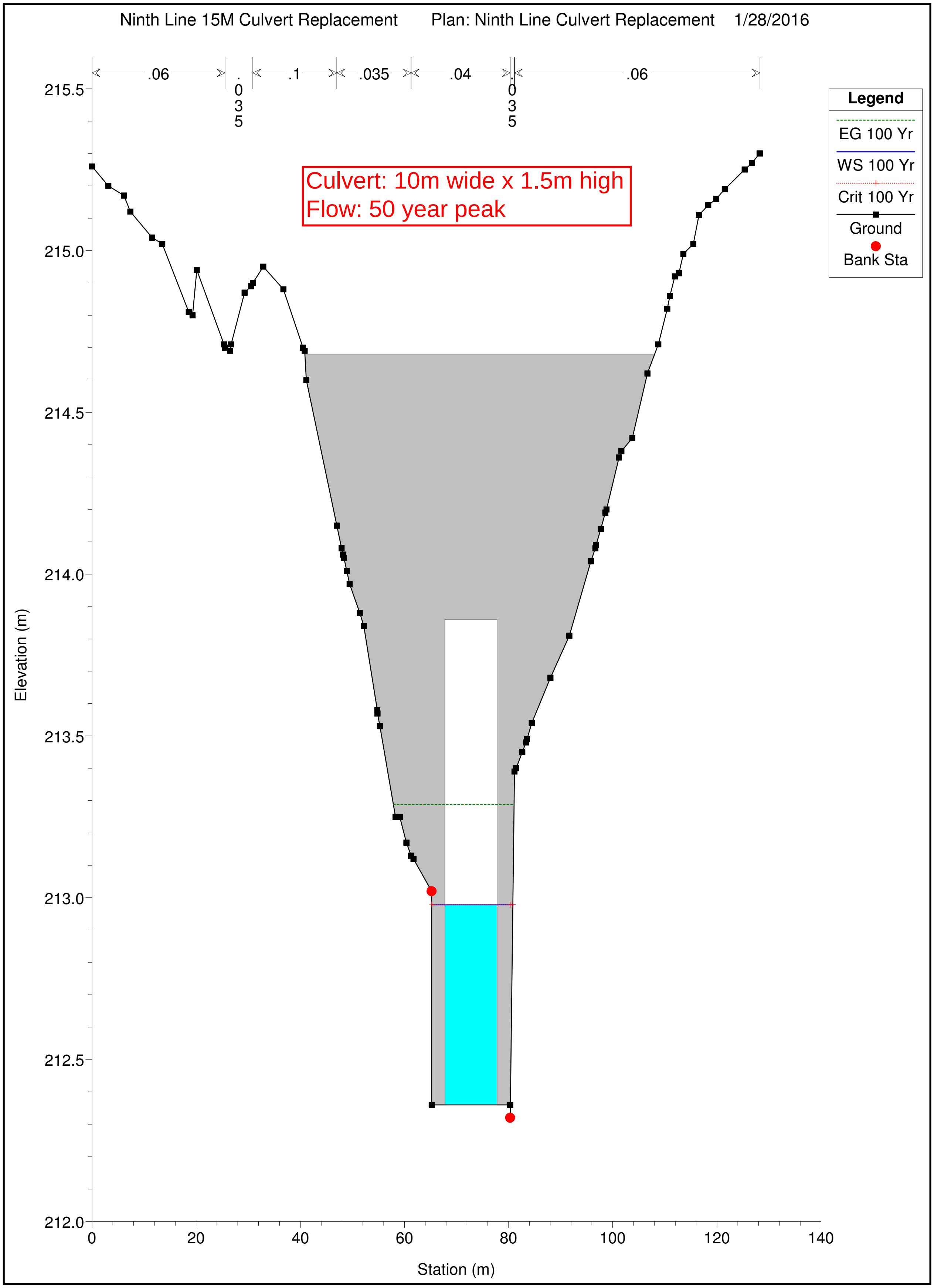




Culvert: 15m wide x 1.5m high
Flow: Regional Storm peak

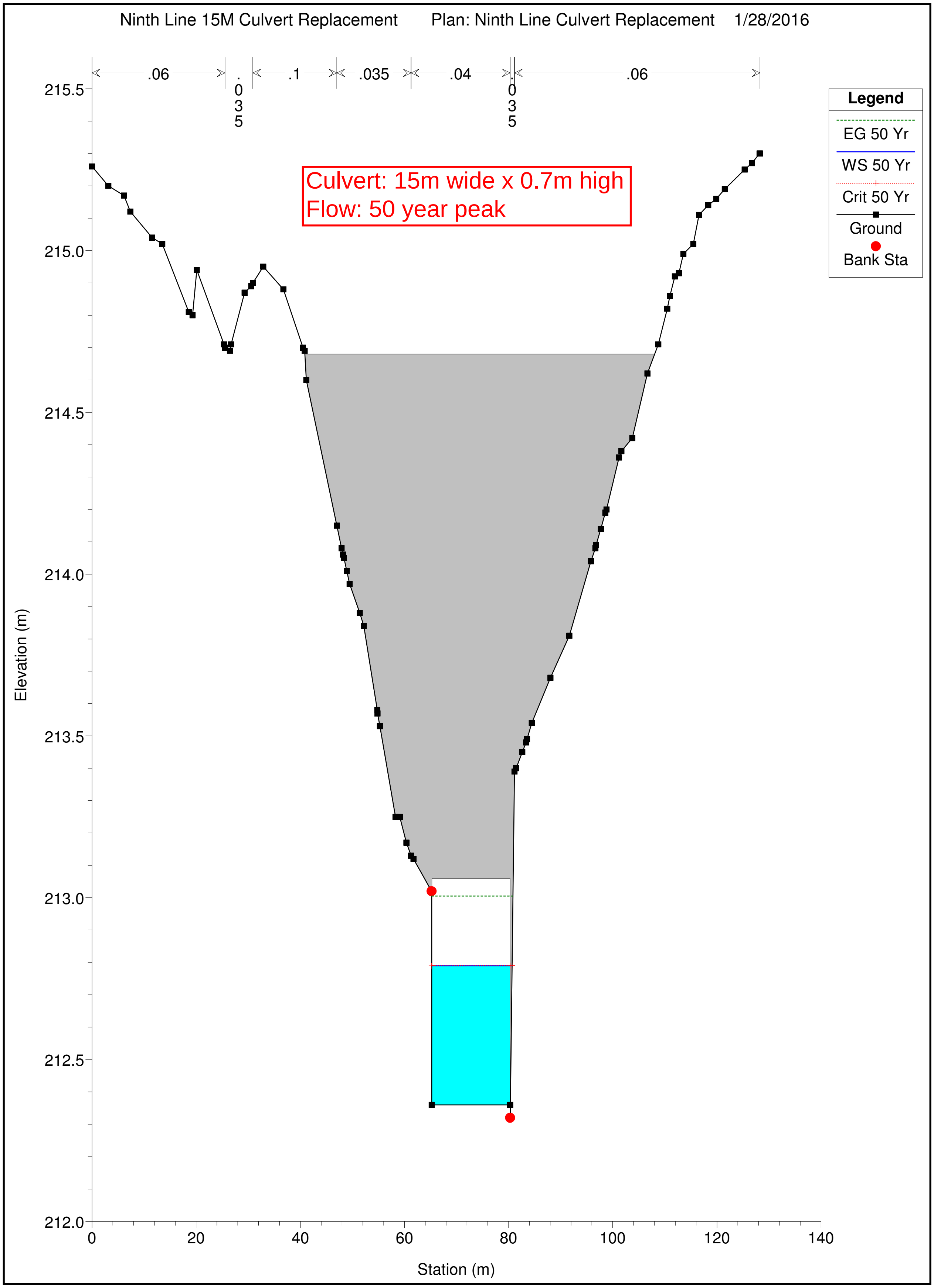

Ninth Line 15M Culvert Replacement Plan: Ninth Line Culvert Replacement 1/28/2016
.06
.035
.1
.035
.04
.035
.06
Culvert: 3m wide x 0.7m high
Flow: 50 year peak
Legend
EG 50 Yr
WS 50 Yr
Crit 50 Yr
Ground
Bank Sta
215.5
215.0
214.5
214.0
213.5
213.0
212.5
212.0
Elevation (m)
0
20
40
60
80
100
120
140
Station (m)

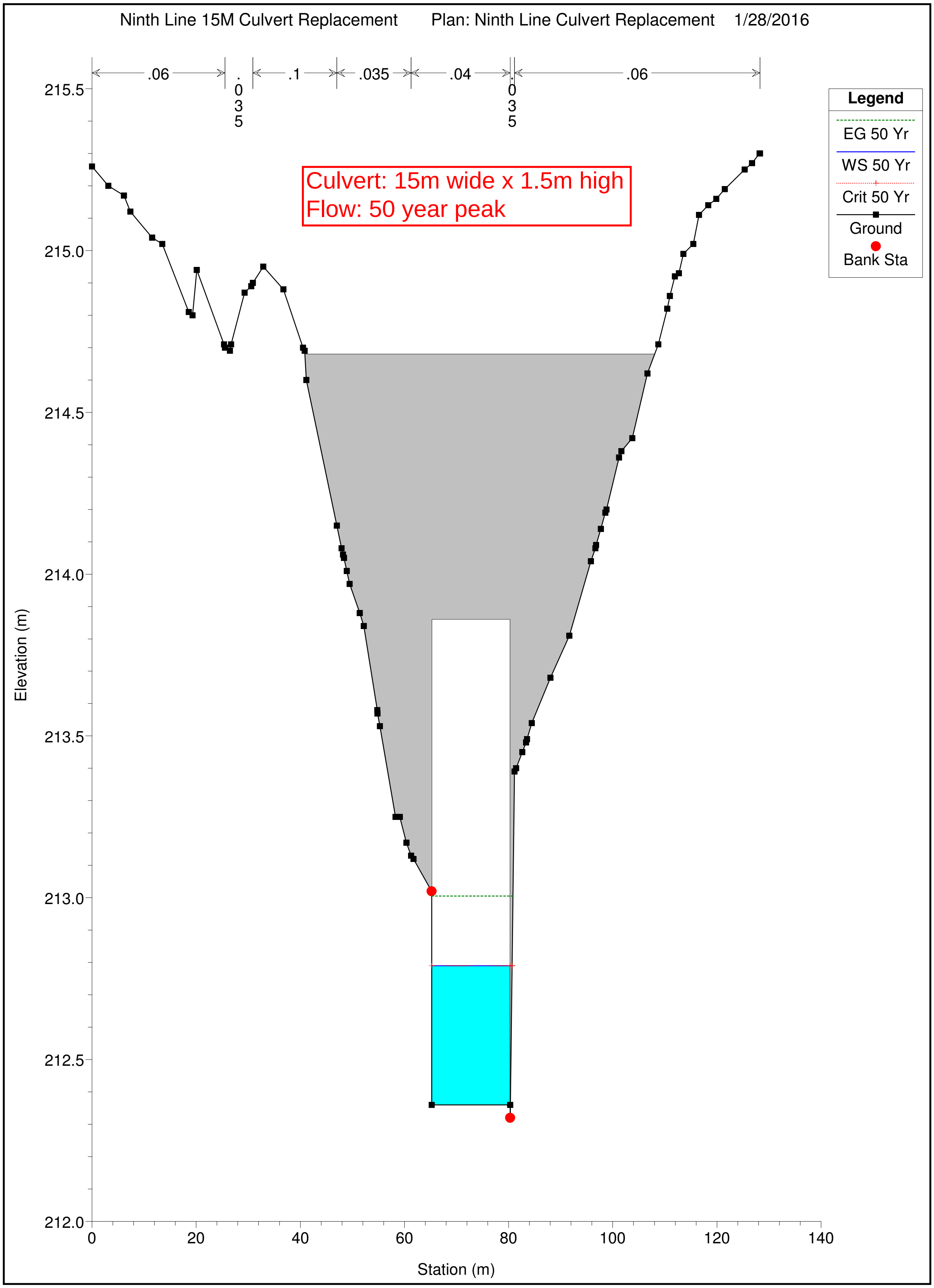

Ninth Line 15M Culvert Replacement Plan: Ninth Line Culvert Replacement 1/28/2016
.06
.035
.1
.035
.04
.035
.06
Culvert: 10m wide x 0.7m high
Flow: 50 year peak
Legend
EG 50 Yr
WS 50 Yr
Crit 50 Yr
Ground
Bank Sta
Elevation (m)
215.5
215.0
214.5
214.0
213.5
213.0
212.5
212.0
0
20
40
60
80
100
120
140
Station (m)



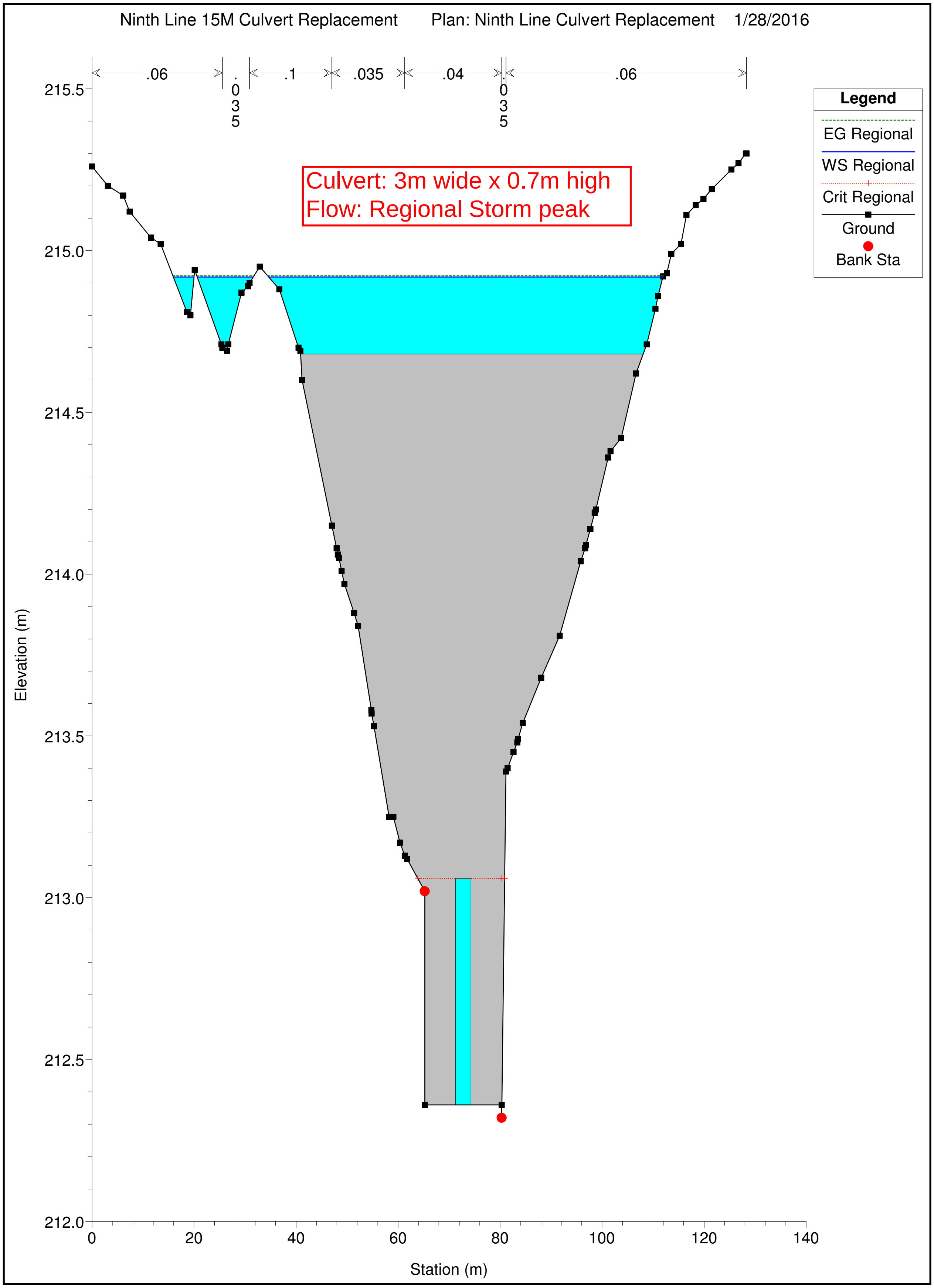
Ninth Line 15M Culvert Replacement Plan: Ninth Line Culvert Replacement 1/28/2016

Culvert: 10m wide x 1.5m high
Flow: 50 year peak

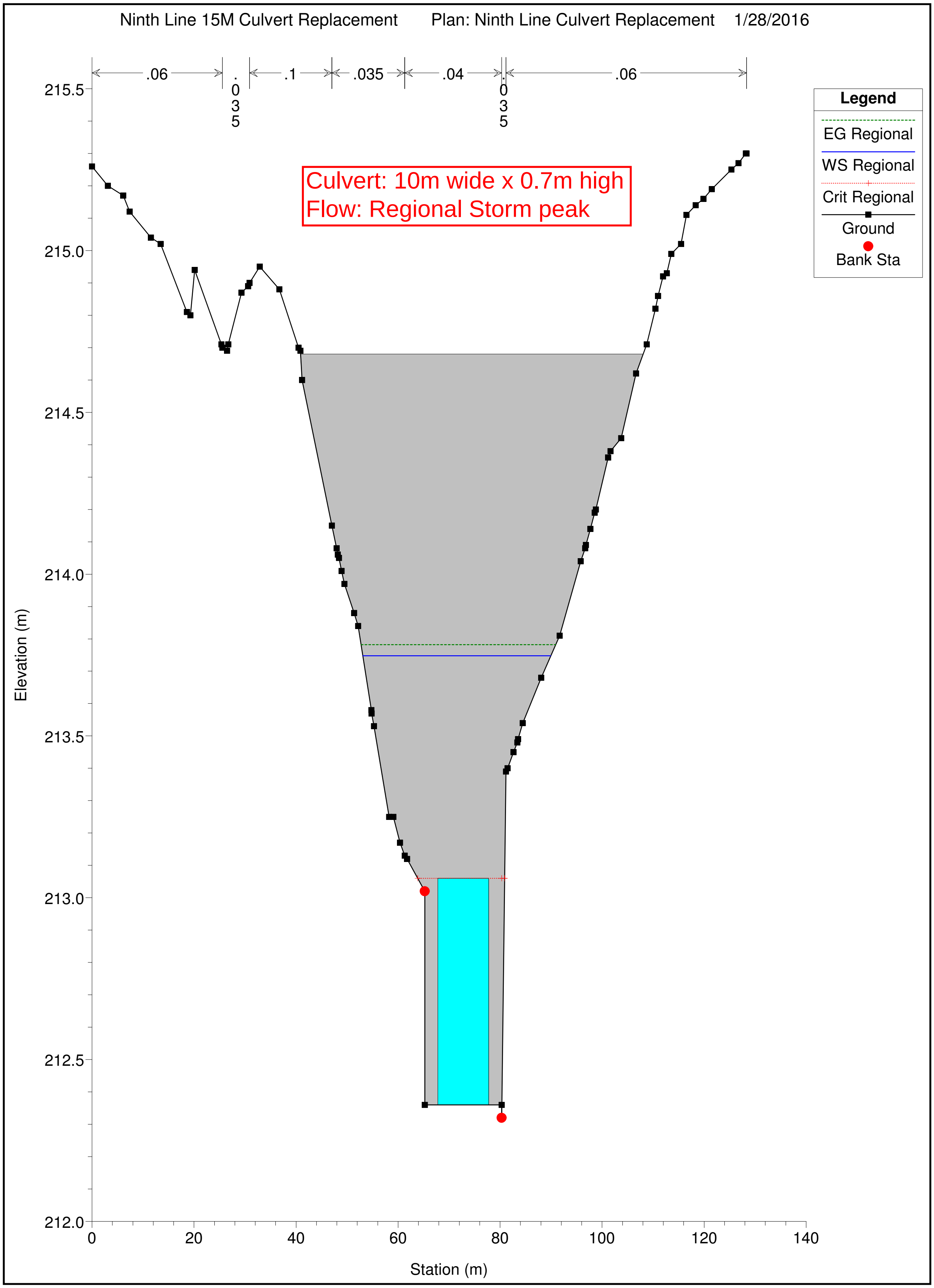

Ninth Line 15M Culvert Replacement
Plan: Ninth Line Culvert Replacement
1/28/2016
.06
.035
.1
.035
.04
.035
.06
Culvert: 15m wide x 0.7m high
Flow: 50 year peak
Legend
EG 50 Yr
WS 50 Yr
Crit 50 Yr
Ground
Bank Sta
Elevation (m)
215.5
215.0
214.5
214.0
213.5
213.0
212.5
212.0
0
20
40
60
80
100
120
140
Station (m)


Ninth Line 15M Culvert Replacement Plan: Ninth Line Culvert Replacement 1/28/2016

Culvert: 15m wide x 1.5m high
Flow: 50 year peak

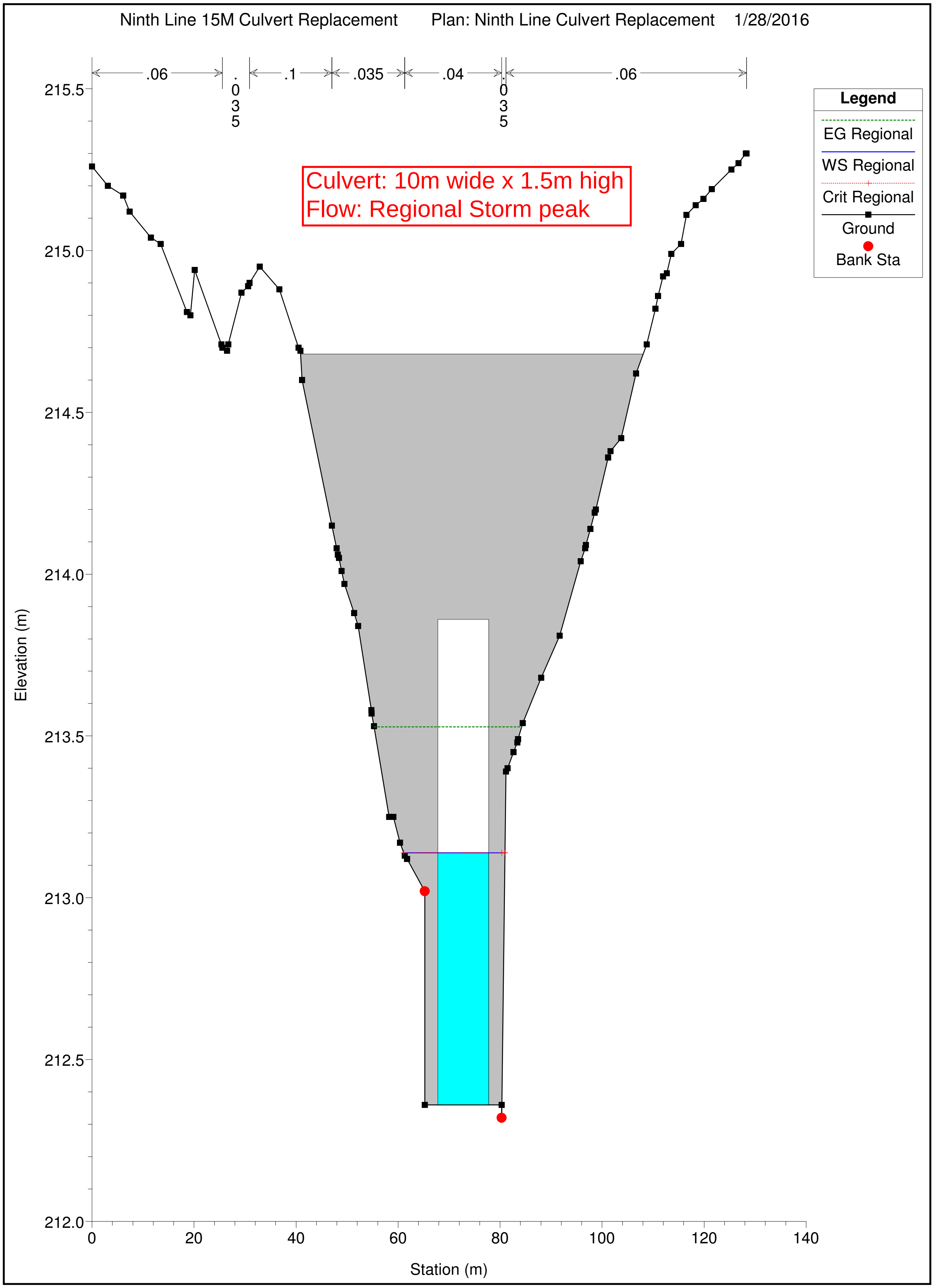

Ninth Line 15M Culvert Replacement   Plan: Ninth Line Culvert Replacement   1/28/2016

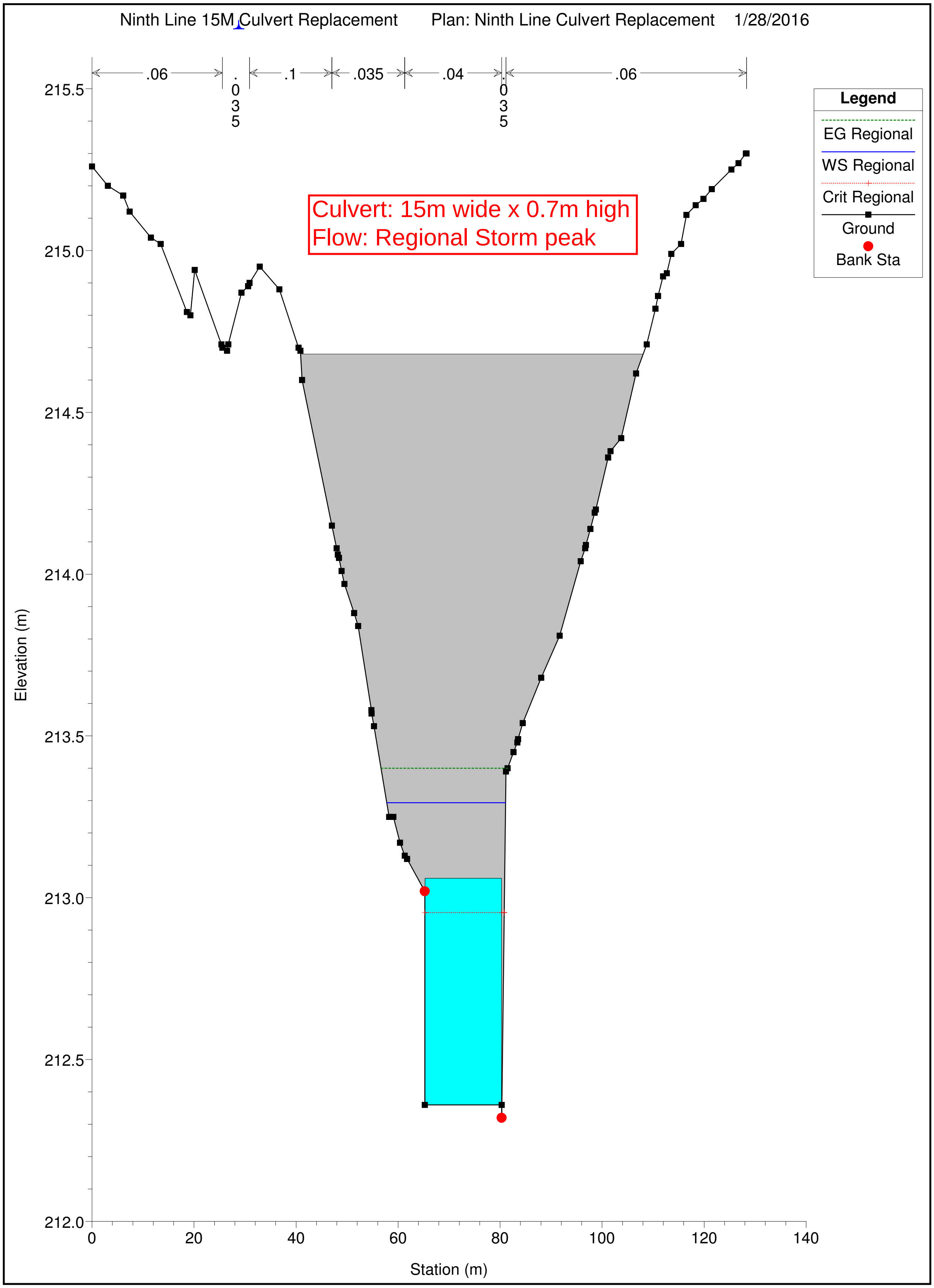
Culvert: 3m wide x 0.7m high
Flow: Regional Storm peak



Ninth Line 15M Culvert Replacement Plan: Ninth Line Culvert Replacement 1/28/2016

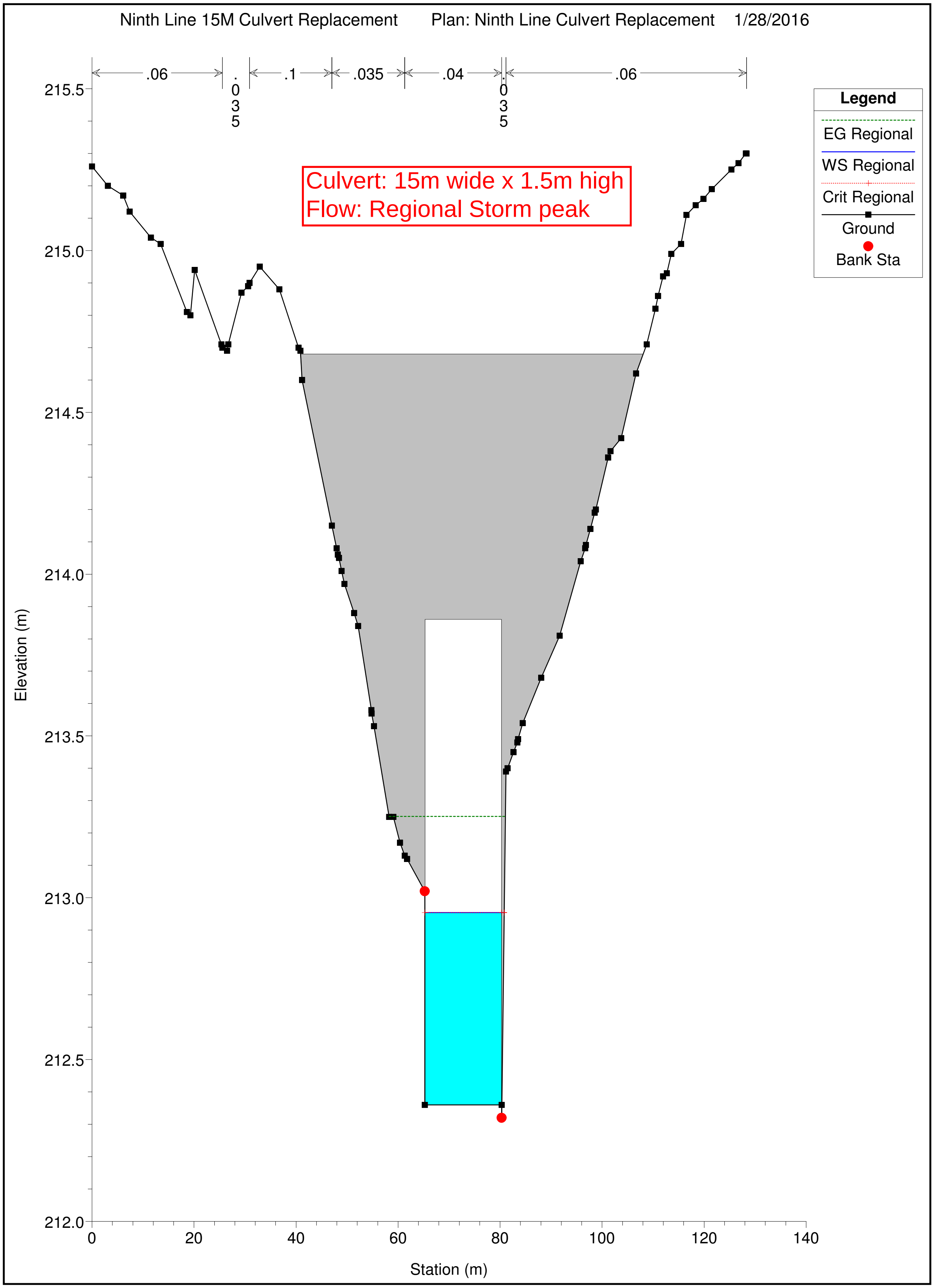
Culvert: 10m wide x 0.7m high
Flow: Regional Storm peak


Ninth Line 15M Culvert Replacement
Plan: Ninth Line Culvert Replacement
1/28/2016
.06
.035
.1
.035
.04
.035
.06
Culvert: 10m wide x 1.5m high
Flow: Regional Storm peak
Legend
EG Regional
WS Regional
Crit Regional
Ground
Bank Sta
Elevation (m)
215.5
215.0
214.5
214.0
213.5
213.0
212.5
212.0
0
20
40
60
80
100
120
140
Station (m)



Ninth Line 15M Culvert Replacement Plan: Ninth Line Culvert Replacement 1/28/2016

Culvert: 15m wide x 0.7m high
Flow: Regional Storm peak


Ninth Line 15M Culvert Replacement Plan: Ninth Line Culvert Replacement 1/28/2016
.06
.035
.1
.035
.04
.035
.06
Culvert: 15m wide x 1.5m high
Flow: Regional Storm peak
Legend
EG Regional
WS Regional
Crit Regional
Ground
Bank Sta
Elevation (m)
215.5
215.0
214.5
214.0
213.5
213.0
212.5
212.0
0
20
40
60
80
100
120
140
Station (m)

Open Channel Capacity of Main Culvert Crossing

	Peak Flow (cms)	Existing 3m x 0.7m Box Culvert	Proposed 3m x 0.7m Box Culvert	Proposed 10m x 0.7m Box Culvert	Proposed 10m x 1.5m Box Culvert	Proposed 15m x 0.7m Box Culvert	Proposed 15m x 1.5m Box Culvert
UP Invert (masl)		212.56	212.56	212.56	212.36	212.56	212.36
DN Invert (masl)		212.05	212.05	212.05	211.80	212.05	211.80
Culvert Length (m)		20	42	42	42	42	42
Slope (%)		2.55%	1.21%	1.21%	1.33%	1.21%	1.33%
Culvert Open Channel Capacity (cms) see **MIDUSS Outputs**		**5.1**	**3.5**	**13.9**	**45.4**	**21.5**	**71.8**
2 Yr (cms)	3.8	open	surcharged	open	open	open	open
5 Yr (cms)	6.7	surcharged	surcharged	open	open	open	open
10 Yr (cms)	8.7	surcharged	surcharged	open	open	open	open
25 Yr (cms)	11.3	surcharged	surcharged	open	open	open	open
50 Yr (cms)	13.3	surcharged	surcharged	open	open	open	open
100 Yr (cms)	15.2	surcharged	surcharged	surcharged	open	open	open
Regional (cms)	21.5	surcharged	surcharged	surcharged	open	open	open

Open - modelled peak flow is less than open channel capacity of culvert

Surcharged - modelled peak flow exceeds open channel capacity of culvert

See MIDUSS Outputs for capacity calculations

```
"                MIDUSS Output ----------------------------------------------->"
"                MIDUSS version                         Version 2.25  rev. 473"
"                MIDUSS created                         Tuesday, June 26, 2012"
"           10   Units used:                                          ie METRIC"
"                Job folder:                         Z:\UEM\Projects\2014\500\"
"                14-508 Ninth Line Class EA\3.Technical_Analyses\SWM and
Drainage\MIDUSS"
"                Output filename:                              Box Capacity.Out"
"                Licensee name:                                         M Molek"
"                Company                                                    UEM"
"                Date & Time last used:                1/28/2016 at 10:29:21 AM"


" 52          CHANNEL DESIGN"
"        3.300   User defined steady flow    c.m/sec"
"        0.040   Manning 'n'"
"           0.   Cross-section type: 0=trapezoidal; 1=general"
"        3.000   Basewidth    metre"
"        0.000   Left bank slope"
"        0.000   Right bank slope"
"        0.700   Channel depth    metre"
"        2.550   Gradient   %"
"             Depth of flow                 0.520    metre"
"             Velocity                      2.116    m/sec"
"             Channel capacity              5.120    c.m/sec"
"             Critical depth                0.498    metre"
" 52          CHANNEL DESIGN"


"        3.300   User defined steady flow    c.m/sec"
"        0.040   Manning 'n'"
"           0.   Cross-section type: 0=trapezoidal; 1=general"
"        3.000   Basewidth    metre"
"        0.000   Left bank slope"
"        0.000   Right bank slope"
"        0.700   Channel depth    metre"
"        1.210   Gradient   %"
"             Depth of flow                 0.669    metre"
"             Velocity                      1.645    m/sec"
"             Channel capacity              3.527    c.m/sec"
"             Critical depth                0.498    metre"


" 52          CHANNEL DESIGN"
"        3.300   User defined steady flow    c.m/sec"
"        0.040   Manning 'n'"
"           0.   Cross-section type: 0=trapezoidal; 1=general"
"       10.000   Basewidth    metre"
"        0.000   Left bank slope"
"        0.000   Right bank slope"
"        0.700   Channel depth    metre"
"        1.210   Gradient   %"
"             Depth of flow                 0.287    metre"
"             Velocity                      1.152    m/sec"
"             Channel capacity             13.907    c.m/sec"
"             Critical depth                0.223    metre"
```

```
" 52          CHANNEL DESIGN"
"        3.300   User defined steady flow    c.m/sec"
"        0.040   Manning 'n'"
"           0.   Cross-section type: 0=trapezoidal; 1=general"
"       10.000   Basewidth    metre"
"        0.000   Left bank slope"
"        0.000   Right bank slope"
"        1.500   Channel depth    metre"
"        1.330   Gradient   %"
"             Depth of flow                0.278    metre"
"             Velocity                     1.186    m/sec"
"             Channel capacity            47.576    c.m/sec"
"             Critical depth               0.223    metre"


" 52          CHANNEL DESIGN"
"        3.300   User defined steady flow    c.m/sec"
"        0.040   Manning 'n'"
"           0.   Cross-section type: 0=trapezoidal; 1=general"
"       15.000   Basewidth    metre"
"        0.000   Left bank slope"
"        0.000   Right bank slope"
"        0.700   Channel depth    metre"
"        1.210   Gradient   %"
"             Depth of flow                0.222    metre"
"             Velocity                     0.990    m/sec"
"             Channel capacity            21.450    c.m/sec"
"             Critical depth               0.170    metre"


" 52          CHANNEL DESIGN"
"        3.300   User defined steady flow    c.m/sec"
"        0.040   Manning 'n'"
"           0.   Cross-section type: 0=trapezoidal; 1=general"
"       15.000   Basewidth    metre"
"        0.000   Left bank slope"
"        0.000   Right bank slope"
"        1.500   Channel depth    metre"
"        1.330   Gradient   %"
"             Depth of flow                0.216    metre"
"             Velocity                     1.018    m/sec"
"             Channel capacity            75.276    c.m/sec"
"             Critical depth               0.170    metre"


" 38          START/RE-START TOTALS "
"            3   Runoff Totals on EXIT"
"             Total Catchment area                       0.000    hectare"
"             Total Impervious area                      0.000    hectare"
"             Total % impervious                         0.000"
" 19          EXIT"
```

APPENDIX E
Fluvial Geomorphic Assessment Details

UEM URBAN & ENVIRONMENTAL MANAGEMENT INC. PROFESSIONAL CONSULTING SERVICES

Stream Name: East 16MC @ 9th Line culvert, N Steeles

Date: 10 December 2015

Location: Ninth Line Culvert

Reach: Upstream of Box Culvert

Observers: I. Smith

Confined/Unconfined/Transitional: C / [✓ U] / T (Circle One)

Sample Site GPS Coordinates: E (m) approx. 594,600

N (m) approx. 4,827,550

Form/Process	**Geomorphic Indicator**		**Present?**		**Factor Value**
	#	***Description***	***No***	***Yes***	
Evidence of Aggradation (AI)	1	***Lateral/lobate bar***			2/9 = 0.22
	2	***Coarse material in riffles embedded***			
	3	***Siltation in pools***		1	
	4	***Medial bars***			
	5	***Accretion on point bars***			
	6	***Poor lateral/longitudinal sorting of bed materials***			
	7	***Soft/unconsolidated bed***			
	8	***Deposition in/around structures/vegetation/woody debris***		1	
	9	***Deposition in the overbank zone***			
Evidence of Degradation (DI)	1	***Channel worn into undisturbed overburden/bedrock***			3/9 = 0.33
	2	***Elevated tree roots/root fan above channel bed***		1	
	3	***Bank heights increasing downstream***		1	
	4	***Absence of depositional features***		1	
	5	***Scour pools d/s of culverts/storm sewer outlets***			
	6	***Cut face on bar forms***			
	7	***Head cutting due to knick point migration***			
	8	***Terrace cut through older bar material***			
	9	***Suspended armor layer visible in bank***			
Evidence of Widening (WI)	1	***Fallen/leaning trees/fence posts/etc.***			2/9 = 0.22
	2	***Occurrence of large organic/woody debris***			
	3	***Exposed tree roots***		1	
	4	***Basal scour on inside meander bends***		1	
	5	***Basal scour/toe erosion on both sides of channel through riffle***			
	6	***Steep bank angles on most of reach***			
	7	***Length of basal scour > 50% through subject reach***			
	8	***Fracture lines along top of bank***			
	9	***Exposed building foundation, infrastructure (pipes, etc.)***			
Evidence of Planimetric Form Adjustment (PI)	1	***Formation of chute(s)***			2 /7 = 0.29
	2	***Single thread channel to multiple channel***			
	3	***Evolution of pool-riffle form to low bed relief form***		1	
	4	***Cut-off channel(s)***			
	5	***Formation of island(s)***			
	6	***Thalweg alignment out of phase meander form***		1	
	7	***Bar forms poorly formed/reworked/removed***			
Stability Index: SI = [(AI + DI + WI + PI)/(# of Form/Process Categories)]:					***SI =* 0.26**

Adapted from ***MoE Stormwater Management and Planning, Appendix C***, 2003; Rapid Geomorphic Assessment, State of Maine, Appendix J-3, 2007; NCHRP 25-25 (8), Developing Performance Data Collection Protocol for Stream Restoration, 2006.

Notes/Comments:

Stability Index, S.I. indicates transitional channel. Agricultural interference and plough-through primary drivers for transition and instability.

APPENDIX F
Minor Culvert Crossing Size Calculations

STORM SEWER DESIGN SHEET

URBAN & ENVIRONMENTAL MANAGEMENT INC. 25 YEAR IDF CURVE

RATIONAL METHOD

4-May-16

$I=a/(t_c+b)^c$

Where: I = rainfall intensity (mm/hr)

tc = tiime of concentration (min)

coeff. a = **1368.91**

b = **8**

c = **0.789**

Q = 2.78AiR

Where: Q = flow (l/s)

A = area (ha)

R = runoff coefficient

Manning's n = 0.013

OUR FILE: **14-508**

PROJECT: **Ninth Line EA**

DESIGNED BY: **B. Gall**

DRAINAGE AREA			**PEAK FLOW**						**SEWER DESIGN**							
Location	**Discharge Location Chainage**	**Area (ha)**	**R**	**A * R**	**Cum A * R**	**Tc (min)**	**I (mm/hr)**	**Q (L/s)**	**Length (m)**	**Grade (%)**	**Dia (mm)**	**#**	**Capacity (L/s)**	**Vel (m/s)**	**Flow Time (min)**	**% of Capacity**
Discharge 0	0+408	22.3	0.429	9.567	9.567	74.600	42.06	1118.6	30.00	1.00	900	1	1810.3	2.846	0.176	61.8
Discharge 1	1+238	86.7	0.420	36.414	36.414	84.600	38.43	3890.7	30.00	0.53	1050	2	3976.0	2.296	0.218	97.9
Discharge 2	major flow to DP3															
Discharge 3	3+498	73.4	0.420	30.828	30.828	62.000	47.93	4107.5	30.00	0.53	1125	2	4779.1	2.404	0.208	85.9
Discharge 4	See OttHYMO	196.4														

URBAN & ENVIRONMENTAL MANAGEMENT INC. 28-Jan-16

CATCHMENT RUNOFF
100, 25, 2 year storms (for Culverts Capacities)

UEM Project #: **14-508**

Project Name: **Ninth Line**

Designed By: **B. Gall**
Checked By:

100, 5, 2 YEAR IDF CURVES

$$I=a/(t_c+b)^c$$

Where:		100 yr	25 yr	2 yr
	I =	rainfall intensity (mm/hr)		
	tc =	tiime of concentration (min)		
coeff.	a =	1777.20	1368.91	586.10
	b =	9.0	8.0	6.0
	c =	0.795	0.789	0.760

Town of Halton Hills
Guidelines

RATIONAL METHOD

$$Q = 2.78AiR$$

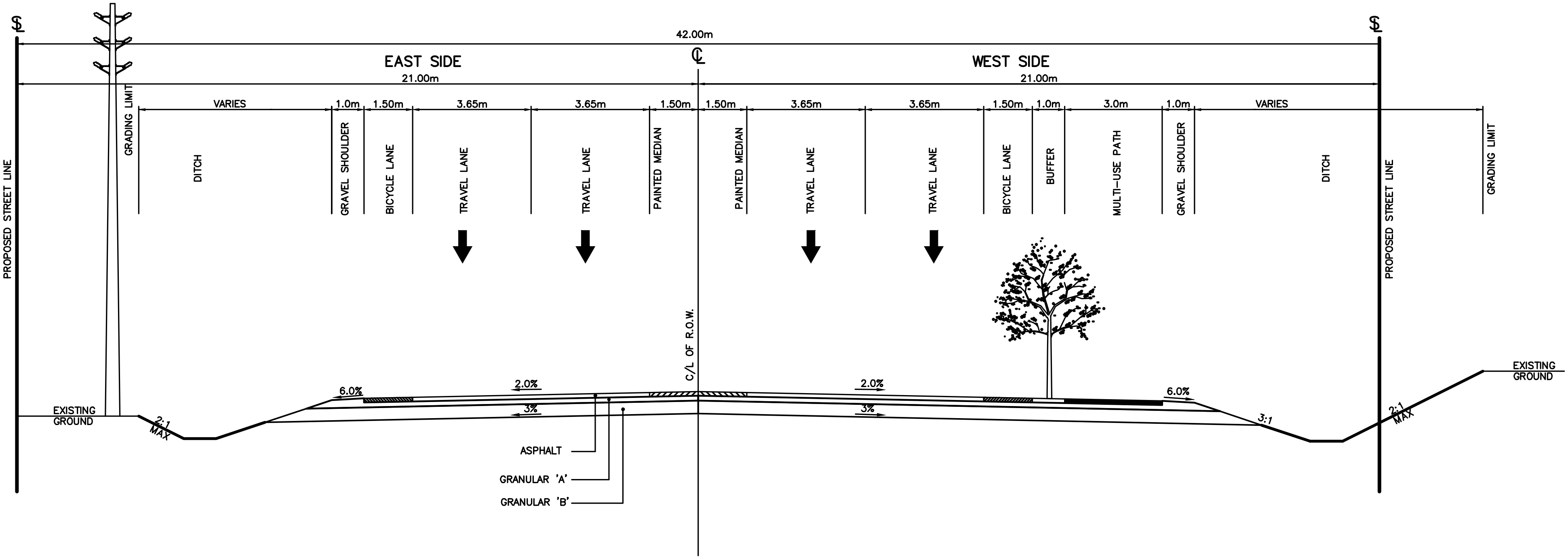
Where:		
	Q =	flow (L/s)
	A =	area (ha)
	R =	runoff coefficient

See MIDUSS Output for "d" and "V" calculations

TC: Airport Method
Q: Rational Method

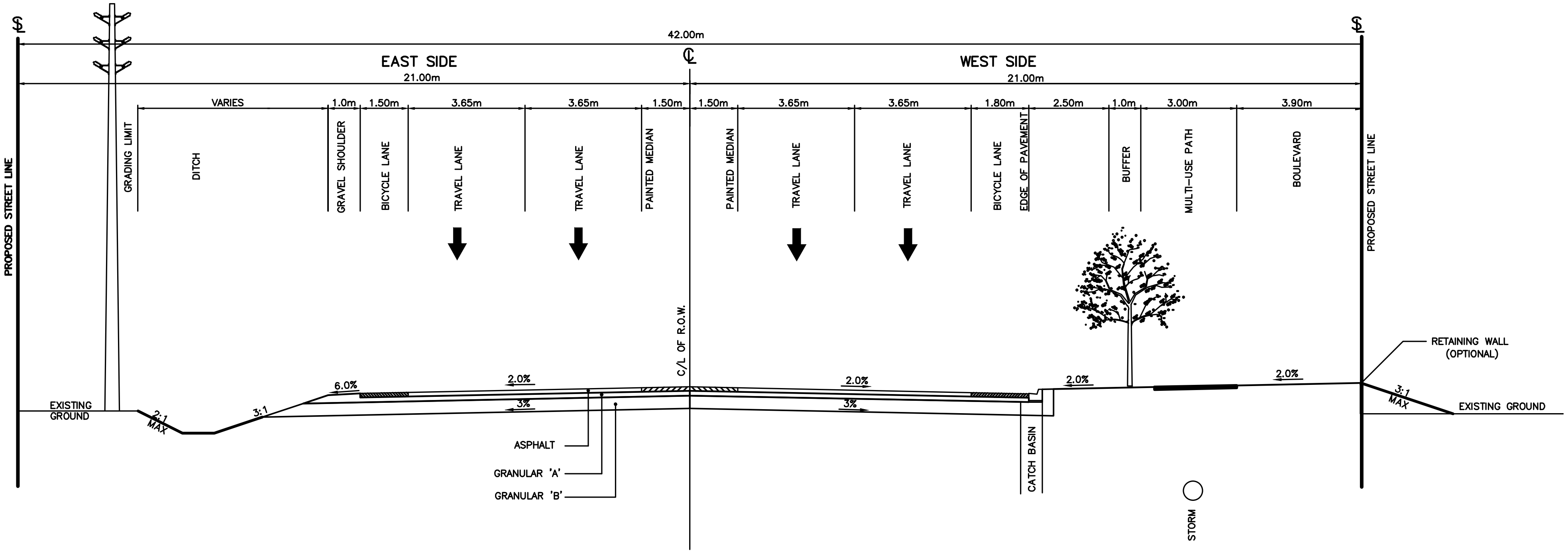
								100yr		25yr		2yr	
RoadCrossing	**Area (ha)**	**Area Cum. (ha)**	**R**	**L (m)**	**Sw**	**Tc (min)**	**A.cum. *R**	**I (mm/hr)**	**Q (m^3/s)**	**I (mm/hr)**	**Q (m^3/s)**	**I (mm/hr)**	**Q (m^3/s)**
Pre 0	0.00	0.00											
Pre 1	109.00	109.00	0.409	1505	1.05	86.0	45	48	**5.9**	38	**4.7**	19	**2.3**
Pre 2	36.30	36.30	0.41	1046	2.30	55.3	15	65	**2.7**	52	**2.1**	26	**1.1**
Pre 3	37.10	37.10	0.408	954	1.38	62.6	15	60	**2.5**	48	**2.0**	24	**1.0**
Pre 4	196.30	196.30	0.404	3565	1.12	130.5	79	35	**7.7**	28	**6.2**	14	**3.1**
Post 0	22.30	22.30	0.43	634	0.40	74.6	10	53	**1.4**	42	**1.1**	21	**0.6**
Post 1	86.70	86.70	0.42	1505	1.05	84.6	36	48	**4.9**	38	**3.9**	19	**1.9**
Post 2	0.00	0.00											
Post 3	73.40	73.40	0.42	1279	2.11	62.0	31	60	**5.1**	48	**4.1**	24	**2.0**
Post 4	196.40	196.40	0.41	3565	1.12	130.0	80	35	**7.8**	28	**6.2**	14	**3.1**

APPENDIX G
Proposed Typical Road Cross-Sections



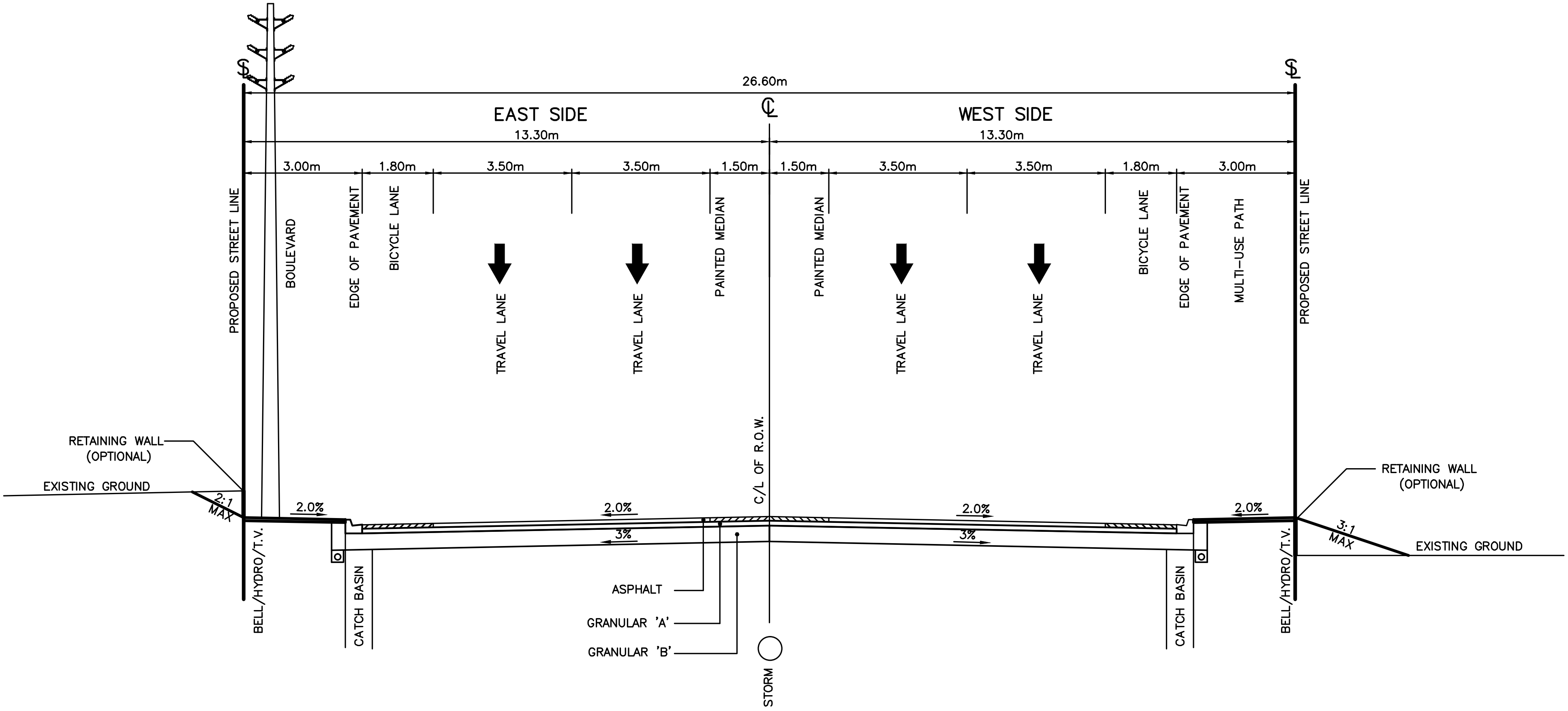
RURAL SECTION 42.0m R.O.W.

SCALE: N.T.S.



SEMI–RURAL SECTION 42.0m R.O.W.

SCALE: N.T.S.

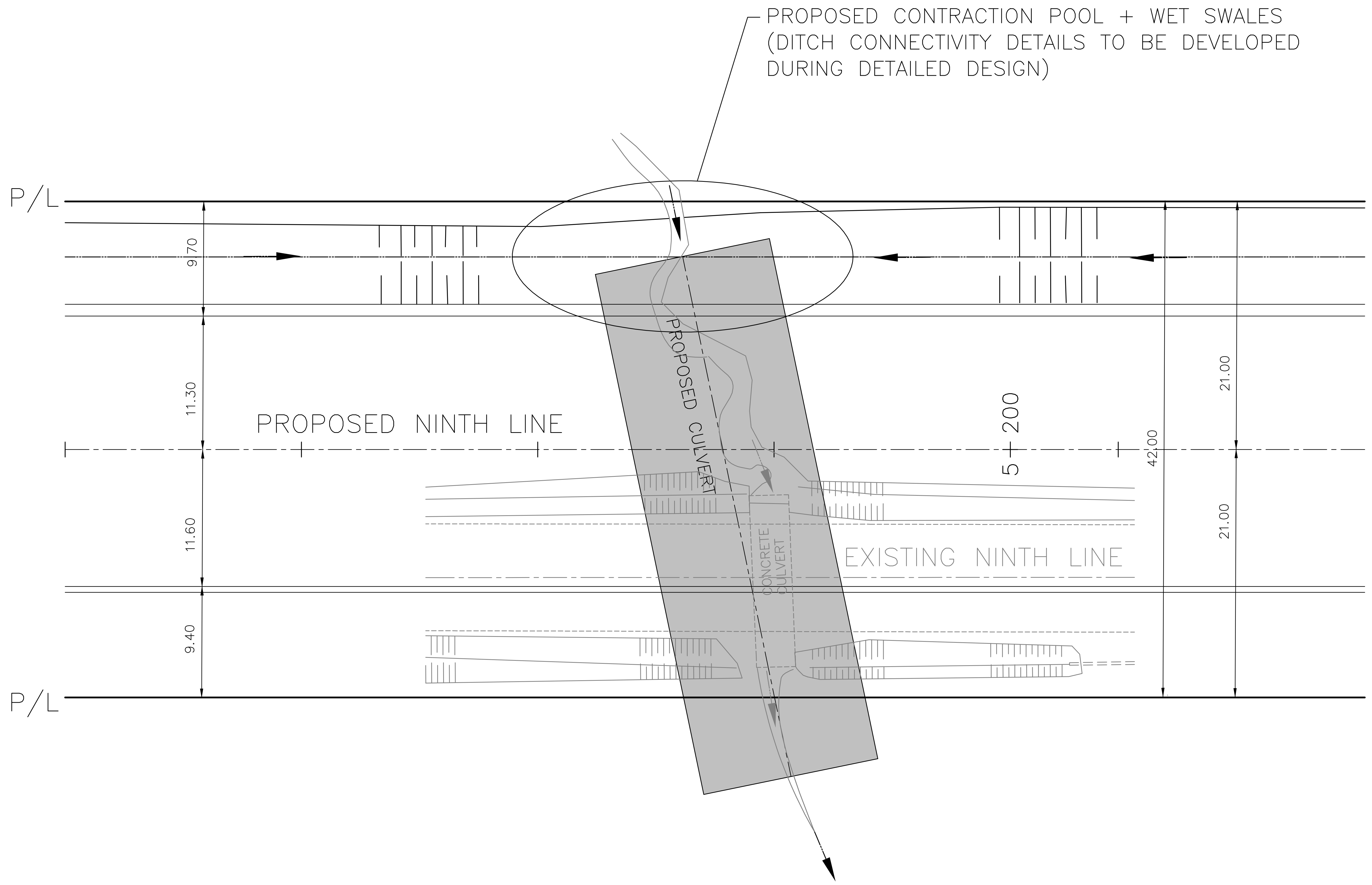


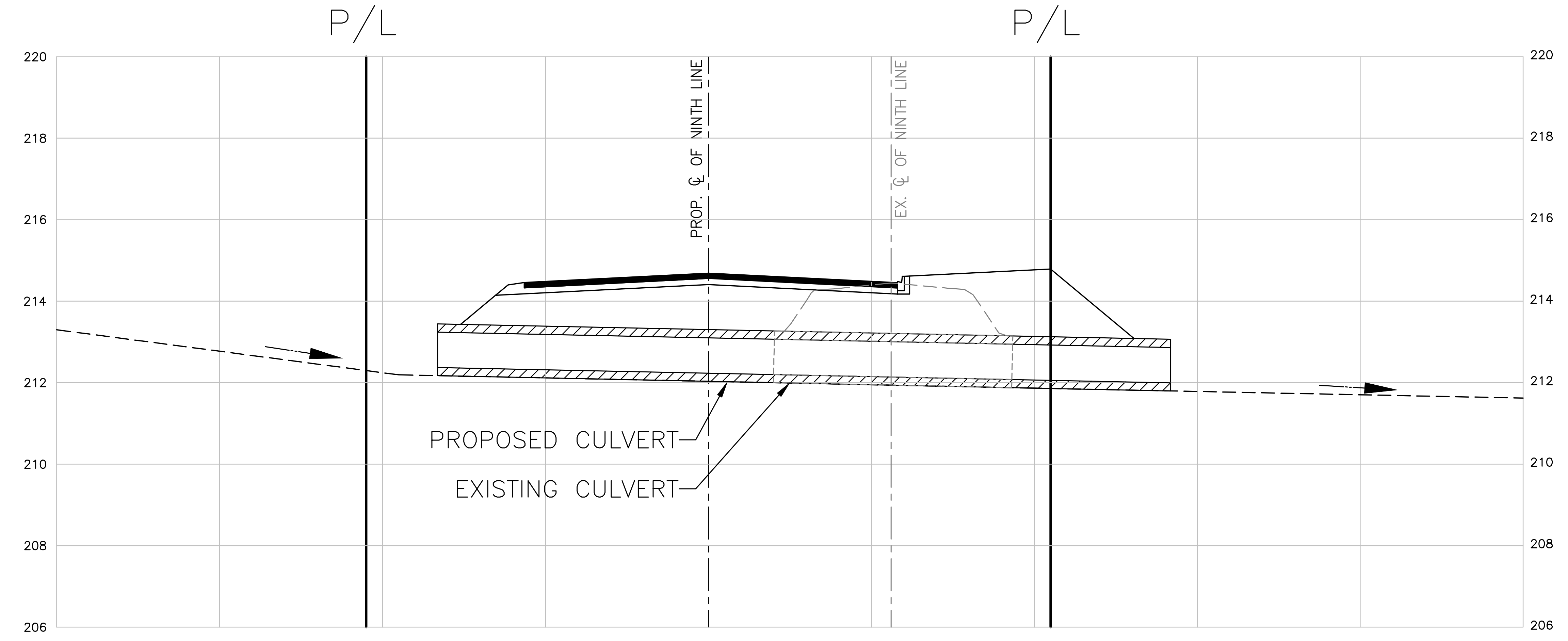
URBAN SECTION – 26.60m R.O.W

SCALE: N.T.S.

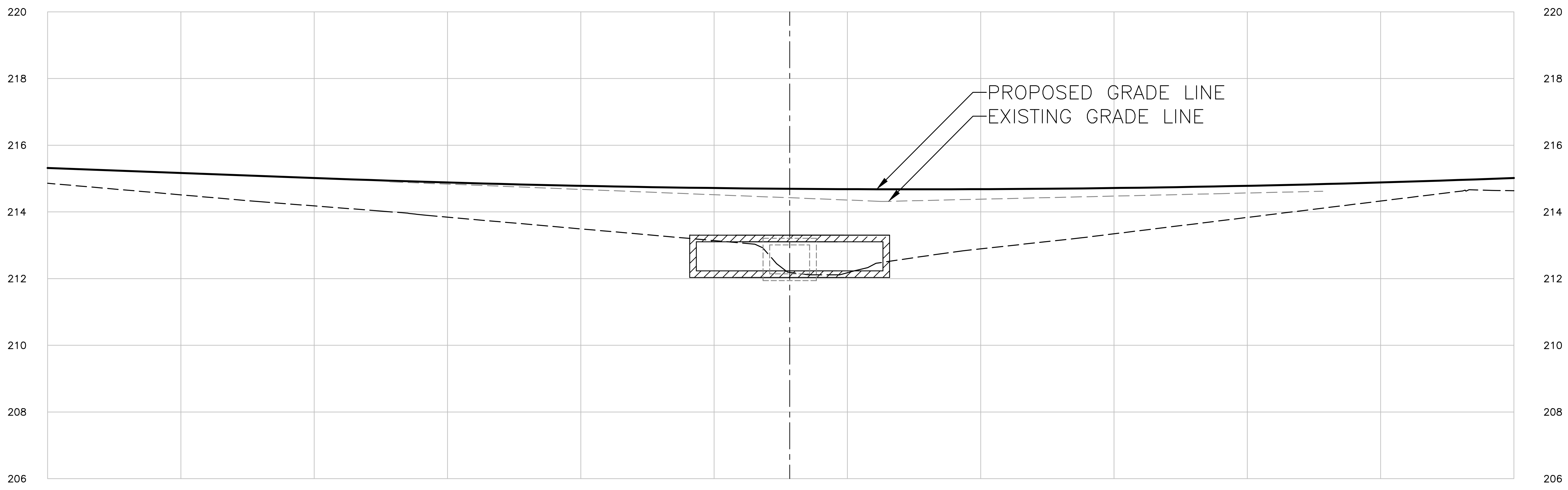
APPENDIX H
Existing and Proposed Box Culvert

HOR. SCALE 1:250
VER. SCALE 1:100





PROPOSED SECTION



PROPOSED PROFILE

Existing & Proposed Box Culvert at Station 5+180

Office Locations

NIAGARA FALLS
4701 St. Clair Avenue, Suite 301
Niagara Falls, Ontario L2E 3S9
Phone: 905.371.9764
Toll Free: 866.840.9764
Fax: 905.371.9763

GTA
5100 Orbitor Drive, Suite 300
Mississauga, Ontario L4W 4Z4
Phone: 905.212.9722
Fax: 905.212.9397

BRANTFORD
120 Colborne Street, Units 106 & 107
Brantford, Ontario N3T 2G6
Phone: 519.752.8686
Fax: 519.752.6419

LONDON
14 Bromleigh Ave.
London, ON N6G 1T9
Phone: 519.472.1975
Email: pflood@uemconsulting.com

www.uemconsulting.com

UEM

EXCEPTIONAL PEOPLE
EXCEPTIONAL SERVICE

A Canadian Company