I1 INTRODUCTION

This section has been prepared to provide Geotechnical Consulting Engineers with a checklist summarizing the geotechnical requirements for a typical ICI (industrial/commercial/institutional) or residential subdivision. This list shall provide many of the general requirements for geotechnical investigations and reports. It is not necessarily exhaustive, and the Geotechnical Consulting Engineer shall be responsible to identify and report upon other issues that they consider relevant to the project.

I2 SITE INVESTIGATION REQUIREMENTS

The following site investigations shall be the minimum standard requirements.

Boreholes shall be placed along the proposed ROW or proposed location of underground structure. The spacing for boreholes shall be examined by the Geotechnical Consulting Engineer and the maximum allowable spacing shall be 150 m. Boreholes shall be advanced to at least 1.0 m below the proposed sewer or underground structure invert grades.

Boreholes shall also be required in locations where other types of municipal infrastructures (e.g. SWM pond, outlet structure, etc.) are proposed and where slope stability assessment is required.

The following tests and investigative works shall be conducted:

1) Standard penetration tests
2) Shear tests
3) Plasticity Index
4) Atterberg limits
5) Resistivity tests
6) Grain size analysis
7) Moisture content
8) Depth of water table at the time of drilling
9) Well monitoring study, if applicable
10) Monitor several boreholes to establish the water table. Ideally, this shall be carried out during both the spring and the summer to establish the seasonal fluctuations
11) California Bearing Ratio (CBR) tests for each representative soil type
12) Depth of topsoil and the identification of any poor soil strata or areas of fill including additional boreholes or test pits
13) Soil type(s) and depth(s) below topsoil

The obtained subsurface information from the investigation program shall be presented graphically in the form of Borehole Logs and the location of the investigation points shall be clearly shown on the plans.

I3 REPORTING REQUIREMENTS

The following, but not limited to, shall be addressed in the Geotechnical Report:

1) Recommended minimum pavement structure including alternative structure during wet weather construction. The pavement structure shall meet or exceed the minimum requirements specified on the City Standard Drawings (MR 35AA).
2) Recommendations with respect to poor sub-grade material including sub-excavation and backfill compaction requirements.

3) Recommended sewer bedding including temporary dewatering requirements during construction, trench stability and trenching requirements as required by the Occupational Health and Safety Act (OHSA).

4) Sub-excavation requirements including the use of filter fabrics (with specifications).

5) Recommended requirements for the placement of engineered fill including the suitability of on-site material.

6) Review the suitability of the City Standards with respect to corrosion protection for watermains.

7) Recommendations for remedial measures for any impacts on adjacent properties, woodlots, natural areas, etc.

8) More project specific requirements may include:

   - Slope stability assessment for both existing and proposed slopes in accordance with the Ministry of Natural Resources and Forestry guideline requirements
   - Foundation requirements for municipal structures
   - Well monitoring of surrounding wells, if applicable

9) Outlines of Geotechnical and Hydrogeology reports shall be in accordance with Annex 2 (Sections 8 and 9).

10) Requirements on temporary or permanent dewatering shall be addressed in the Hydrogeology Report in accordance with Section E (E 11).

11) Stormwater Management (SWM) Ponds recommendations for side slope stability, temporary dewatering requirements/implications and pond bottom sub-grade strength. Determine the requirement of a clay liner for retention ponds.

I4 MATERIAL TESTING

A qualified testing and inspection Consultant(s) shall be retained by the Owner for new developments to provide the following testing and inspection services:

1) Soils, compaction, and asphalt (for bedding, pipe cover, trench backfill, road sub-grade, granular, and asphalt road pavement materials).

2) Concrete (slump, air entrainment, and compressive strength).

3) Reinforcing steel (material strength and placement).

4) Granular testing (gradation, proctor, etc.).

5) Proof-rolling and inspection of sub-grade.

6) Asphalt laboratory tests (Marshall mix design, asphalt content, and gradation).

7) Concrete mix and asphalt mix review.

Copies of all laboratory and field tests shall be provided on a weekly basis to the City's Inspector along with a cover letter outlining any deficiencies noted through the testing process and describing what corrective measures have been or shall be taken. All testing shall be in accordance with OPSS procedures.

Further guidelines on the role of Geotechnical Consulting Engineer are contained in Section F of the "City of Markham Municipal Inspection and Construction Guidelines".

I5 WELL MONITORING REQUIREMENTS

Well Monitoring/Mitigation

Prior to initiating any grading activities on a development site where existing wells may be affected by grading activity or service installation, and when required by the Director of Engineering, the details and methodology of a well monitoring and mitigation program shall be submitted to the Engineering Department for review and acceptance. In addition, the Well Monitoring/Mitigation program shall be subject to peer review by the City's Hydrogeologist or Geotechnical Engineer, at the Owner's cost.

The City may update and/or modify the Well Monitoring/Mitigation program as deemed necessary. The principles of the well monitoring/mitigation program shall include, but not necessarily limited to, the following:

1) Establish baseline conditions including:
   - List all the Ministry of Environment, Conservation, and Parks (MECP) recorded wells in an area defined by the Director of Engineering
   - Inspect, evaluate, and monitor all accessible wells within the Zone of Influence (i.e. minimum 500 m radius from the boundary of the subject site) before, during, and after the construction

2) Prediction:
   - Based on the above information, predictions shall be made regarding the potential zone of impact by dewatering
   - Where predictions indicate that residents or environmental features shall definitely be affected, then a proactive program shall be implemented, including the deepening of pumps or wells as necessary as accepted by the Director of Engineering and other authorities having jurisdictions (TRCA, MECP, MNRF, etc.)

3) Prior to Construction:
   - Provide and distribute a canvassing letter to the residents in the defined area. The canvassing letter shall provide a brief description of the Well Monitoring/Mitigation program along with the names and phone numbers of people to contact in case of an emergency. This letter shall be submitted to the Director of Engineering for review and acceptance prior to distribution.
   - Complete and submit a Baseline Well Condition and Monitoring Report to the City prior to the pre-servicing or registration of the Plan of Subdivision (whichever occurs first).
     a) This report shall include as a minimum the following:
        - Bacteriological analysis (total coliform and e-coli counts)
        - Chemical analysis (nitrate test)
     b) Well water level readings for all accessible wells within the Zone of Influence
     c) A list of all the MECP registered wells within the Zone of Influence
     d) It the test results do not comply with the Ontario Drinking Water Standards, the Owner/Consultant shall notify, in writing, the home owners, York Region's Health Department (environmental manager) and the Director of Engineering within 24 hours of the test results
     e) Well monitoring shall continue during and one year after completion of the servicing activities on 6-8 week intervals

4) Response to reports of water loss:

- Investigate within 12 hours of notification of a well problem and determine a suitable solution for the interim supply of potable water
- Impacts that are expected to last less than three (3) months shall be addressed through temporary tanks
- For impacts that are expected to last over three (3) months, the proposed solutions in the order of precedence are as follows:
  - If possible, lower pump within the existing wells that may be affected
  - If possible, deepen and upgrade the existing well
  - Drill a new and deeper well, if necessary
  - Where feasible, connect the residence to local municipal distribution watermain

I6 RECYCLED ASPHALT PAVEMENT (RAP)

The OPSS permits the use of RAP in asphalt mixes. The Director of Engineering may allow the use of RAP in the following amounts, subject to satisfactory demonstration of quality control:

- HL3 or any surface course mixes – use of RAP is **not** permitted
- HL8 binder mixes - up to 15%
- Use of RAP in HL8 mixes over 15% must have written acceptance from the Director of Engineering
- Dense Friction Course (DFC), Stone Mastic Asphalt (SMA), and Heavy Duty Binder Course (HDBC) - use of RAP is not permitted in these premium mixes

Suppliers and contractors must verify to the Director of Engineering the amount of RAP being used and the quality of the blended mixes.

The amount of RAP being used in asphalt mixes must be indicated on the mix design and that all aspects of the physical and Marshall Properties of the asphalt mix meet the OPSS requirements. The RAP percentages used during mix production shall be verified through asphalt plant inspections and through a review of quality control procedures and reporting by the City's Inspectors.

Periodic, independent quality assurance testing of the asphalt mixes must be undertaken to confirm conformance to the Job Mix Formula. A copy of the batch weights of the mixes shall be made available on a weekly basis and City's Inspectors may attend plant inspections and view mix proportions.

I7 USE OF RECLAIMED ASPHALT PAVEMENT (RAP) IN ROAD BASE

The Director of Engineering may allow the use of RAP in road base as per the details given below:

- Granular 'A' and Granular 'B', Type I, may be allowed up to 30% RAP by mass
- Granular 'B', Type II and Crusher-Run base material shall not contain any RAP and shall only be obtained from crushing quarried bedrock

I8 USE OF RECLAIMED ASPHALT PAVEMENT (RAP) IN PIPE BEDDING

The RAP is **not** accepted in the City for use in pipe bedding.

I9 USE OF RECYCLED CONCRETE MATERIAL (RCM) FOR ROAD BASE /SUBBASE

PART 1: GENERAL

1.1 Description

1) This specification covers the supply of recycled structural concrete material for use as the road base/subbase in pavements and related engineering construction.
2) This specification defines two processed aggregate products for use as Granular A and Granular B Type I (modified).
3) RCM is not approved for use as sewer bedding material, backfill of concrete structures (e.g. behind abutments), or for any exposed granular road applications.

1.2 Reference Standards

1) Ontario Provincial Standards Specifications (OPSS):
   a) OPSS 314 - Untreated Granular, Subbase, Base, Surface, Shoulder, and Stockpiling.
   b) OPSS 501 - Compacting
   c) OPSS 1001 - Aggregates - General
   d) OPSS.MUNI 1004 - Aggregates - Miscellaneous
   e) OPSS.MUNI 1010 - Aggregates - Base, Subbase, Select Subgrade and Backfill Material
   f) Ministry of Transportation, Ontario - Laboratory Testing Manual

1.3 Definitions

1) Recycled Concrete (RC) - Reclaimed concrete generated from the following two sources:
   a) Concrete from demolished infrastructure; and
   b) Returned to Plant Concrete.
2) Recycled Concrete Materials (RCM) - Construction aggregate produced from crushing and processing Recycled Concrete for use in construction.

PART 2: MATERIALS

2.1 Source Concrete for Production of RCM

1) Concrete from demolished infrastructure produced from crushing and screening reclaimed concrete from rigid or composite pavements, bridges, sidewalks, curbs and/or other structural concrete.
2) The source recycled concrete shall consist of conventional Portland cement concrete with or without supplementary cementitious materials.
3) The recycled concrete shall be free from reinforcing steel (black, epoxy coated, GFRP, steel mesh or other embedded objects).

4) The recycled concrete shall be free from deleterious materials (i.e. roots, leaves, wood, plastics, organics, bricks, cinder blocks, mortar, tiles, gypsum, plaster, clay-based materials etc.).

5) Concrete that has undergone chemical degradation, such as from alkali aggregate reactivity and internal sulphate attack, shall not be used as source concrete for the production of RCM.

6) Upon request, the contractor shall allow the City or City's representative the right to enter upon the premises of any of the RCM material manufacturers, suppliers, plants, laboratories, or equipment for purposes pertaining to the work, to carry out such inspection, sampling, and testing as specified or as requested by the City or City's representative.

PART 3: MATERIAL QUALITY

3.1 Recycled Concrete

1) Upon request, the supplier must provide the City with proof of the following:

   a) The material was pre-approved at the receiving facility as originating from an approved and acceptable source. (*This is to ensure that the RC does not contain bricks, boards or any other deleterious materials. The receiving facility's personnel should inspect the originating site before delivery to the recycling yard*).

2) Upon request, the supplier must provide the City with written records of the types and sources of reclaimed materials received at the recycling yard for the production of RCM.

3) Upon request, the supplier must provide the City with gradation control charts performed at a frequency of at least one for every 1,000 tonnes of RCM production.

4) The supplier must provide test certificates from a valid CCIL certified laboratory, no older than one year prior to the date of supply, confirming that the material complies with the requirements of this specification.

PART 4: TEST METHODS

4.1 General

1) RCM shall comply with the requirements of the latest edition of OPSS.MUNI 1010 unless otherwise designated.

2) RCM shall satisfy the requirements of Tables 1, 2a and 2b, 3, 4, 5, and 6.

3) Summary of required Testing and frequency is provided in Flow Chart at the end of Section 4.4.

4.2 Laboratory Test Methods

1) Recycled concrete material to be used in road base/subbase applications shall be tested in accordance with the test methods described in Table 1.

Table 1: Standard Test Methods

Laboratory Test	Specification and Test Number
Percent crushed particles, % minimum	LS-607
Micro-Deval Abrasion Coarse Aggregate, % maximum loss	LS-618
Asphalt Coated Particles, % maximum	LS-621
Amount of Contamination	LS-630
Plasticity Index, maximum	LS-703/704
Determination of Permeability, k	LS-709
Sieve Analysis, % Passing	LS-602
Moisture-Density Relationship of Soils Using 5.5 kg Rammer and 305 mm Drop	LS-706
Determination of water-soluble sulphate ion content of recycled aggregates containing crushed concrete	CSA A23.2-8B

4.3 Pre-Qualification of Existing Stockpile

1) If a supplier requests to have an existing RCM stockpile pre-qualified for use as road base/subbase, the RCM stockpile must have been generated within the previous 12 months and must satisfy the following conditions in order for the stockpile to be deemed acceptable for use:

   a) The supplier will have to demonstrate through control charts or equivalent (generated during the production of the subject RCM stockpile) that the RCM stockpile to be used satisfies the physical property and gradation testing requirements of this specification.

   b) Prior to first use, the supplier must provide the City with current physical property and gradation testing results demonstrating that the RCM stockpile satisfies the requirements of this specification. Following this acceptance of the stockpile, the sampling, and frequency of subsequent testing shall be in accordance with Table 3.

   c) Approval of RCM will be considered on a stockpile basis only. Additional submissions for approval will be required should the stockpile sources change.

4.4 Quality Assurance Sampling and Frequency of Testing RCM

1) Sampling of RCM shall be in accordance with LS-625.

2) At least three weeks prior to the project start, the source stockpile shall be sampled by the Contractors or Contractors representative and tested in accordance with Tables 4, 5, and 6. Testing results shall be provided to the City for review prior to project commencement.

3) Upon delivery of the RCM material to site, the site stockpile shall be sampled by the City or City's representative and tested testing in accordance with Tables 4, 5, and 6 (excluding Table 4 - Permeability Testing).

4) During production, the RCM material shall be sampled and tested on a daily basis in accordance with Table 5.

5) The QA sampling and testing frequency during production shall be according to Tables 2a, 2b, and 3 or as described in the Flow Chart in Figure 1.

6) Table 2a shall apply to the following physical property testing: Percent Crushed content, Micro-Deval testing, Asphalt Coated Particles, Amount of Contamination, and Plasticity Index.

7) Table 2b shall apply to the following physical property testing: Determination of Permeability.

Table 2a: Sampling and Testing Frequency - Physical Property Testing (excluding Determination of Permeability)

Quantity from Each Source or Process, tonne	Granular A and Granular B Type I (Modified)
< 2,500	Two samples
≥ 2,501 to 10,000	Four Samples (one Sample for every 2,500 tonnes)
≥ 10,001	One Sample for every 2,500 tonnes followed by One sample for every 5,000 tonnes thereafter

Table 2b: Sampling and Testing Frequency – Determination of Permeability[1]

Quantity from Each Source or Process, tonne	Granular A and Granular B Type I (Modified)
Up to 10,000	One sample every 2,500 tonnes up to 10,000 tonnes
≥ 10,001	One sample every 2,500 tonnes up to 10,000 tonnes followed by One sample for every 5,000 tonnes thereafter

Notes:

1. The sampling and testing frequency requirements for Permeability testing will be based on the testing results. Subsequent testing will be at the discretion of the City.

Table 3: Sampling and Testing Frequency - Gradation Testing

Quantity from Each Source or Process, tonne	Granular A and Granular B Type I (Modified)
< 250	One sample
≥ 251 to 1,000	Two samples (one Sample for every 500 tonnes)
≥ 1,001	One Sample for every 1,000 tonnes up to 3,000 tonnes followed by One sample for every 2,000 tonnes thereafter

Table 4: Physical Property Requirements

MTO Laboratory Test and Number	Granular A	Granular B Type I (Modified)
Percent crushed particles, % minimum, LS-607	75	N/A
Micro-Deval Abrasion Coarse Aggregate, % maximum loss, LS-618	25	30
Asphalt Coated Particles, % maximum, LS-621	30	30
Amount of Contamination, % LS-630	(Note 1)	
Plasticity Index, maximum, LS-703/704	0	
Determination of Permeability, k, LS-709	>1.0 x 10^{-5} cm/s	

Notes:

1. At the discretion of the City, the Granular A and Granular B Type I (modified) may contain crushed glass or ceramic materials up to a combined total of 15% by mass. Granular A and Granular B Type I (modified) shall not contain more than 1% by mass of wood, clay brick and/or gypsum and/or gypsum wall board or plaster.

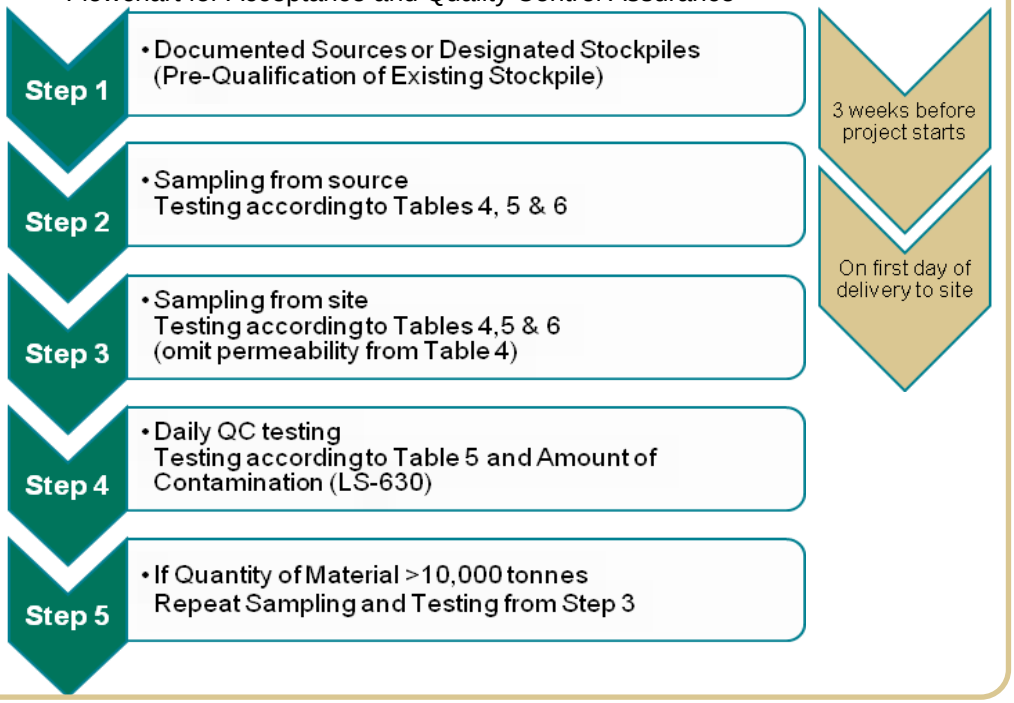
Table 5: Gradation Requirements - Percent Passing

MTO Test	Sieve	Granular A	Granular B Type I (Modified)
LS-602	106 mm	N/A	100
	26.5 mm	100	50-100
	19.0 mm	85-100	N/A
	13.2 mm	65-90	N/A
	9.5 mm	50-73	N/A
	4.75 mm	35-55	20-55
	1.18 mm	15-40	10-40
	300 µm	5-22	5-22
	150 µm	N/A	N/A
	75 µm	2.0-8.0	0-10.0

Table 6: Chemical Property Requirements

Laboratory Test and Number	Granular A	Granular B Type I (Modified)
Determination of water-soluble sulphate ion content of recycled aggregates containing crushed concrete, SO_4, CSA A23.2-8B	(Note 1)	
Notes: 1. The RCM material shall satisfy the requirements of CSA A23.1 - Table 3.		

Figure 1 – RCM for Road Base/Subbase
Flowchart for Acceptance and Quality Control Assurance



PART 5 – EXECUTION

5.1 Placing RCM Material

1) The RCM should be placed according to OPSS 314 unless specified elsewhere in the contract documents.
2) If RCM is segregated following compaction, the segregated layer should be removed and replaced full depth.
3) RCM Granular A and Granular B Type I (modified) materials shall have a 1:1 equivalency as compared to virgin materials.

5.2 Rolling and Compaction

1) Compact the RCM according to Method A of OPSS 501.
2) Compact the RCM to 100% of the materials Standard Proctor Density.
3) Apply water as necessary during compaction.
4) For areas not accessible to conventional rolling equipment, use hand tampers not weighing less than 25 kg or equivalent to achieve the desired compaction.
5) The surface of the RCM material should be shaped to be smooth, even, and uniformly compacted following rolling.

I10 VIBRATION MONITORING

Prior to initiating any construction activities on a development site where existing structures and buried utilities may be affected by vibration from heavy construction operations, including but not limited to, jack and bore operations, auger boring, pipe ramming operation, excavation, dynamic compaction, backfill compaction, road base compaction, driven piles, drilled caissons including solider piles with lagging, and contiguous caisson walls used for temporary and permanent shoring, sheet piling for shoring, and demolishing of existing structures, etc., vibration monitoring shall be carried out per guidelines given below:

1) Typical construction vibrations maximum values given in the table below:

Frequency (Hz)	***** **Peak particle Velocity (PPV) [mm/s]**
Less than 4	8
From 4 to 10	15
More than 10	25

** Peak particle velocity shall be measured using tri-directional digital seismographs*

The values given above are guidelines only. The Consulting Engineer/Owner is responsible to ensure that no damage occurs to any buildings/structures due to vibration.

2) A ”Zone of Influence” (ZOI) is typically established. The ZOI is the area outside of which construction vibrations do not exceed 5 mm/s at any frequency. A vibration monitoring program may not be required where buildings or structures are outside the ZOI.

3) Various consultation, inspection, communications protocols, and processes are required to be established in the monitoring program.

4) In some cases, more stringent criteria will be or may be appropriate. The Consulting Engineer shall be responsible to identify such cases and the selection of the appropriate criteria, as necessary.

5) Criteria for annoyance due to ground-borne vibration are generally more stringent than for possible structural damage. The suggested cautionary vibration criteria are summarized in the Table below. Vibration monitoring may not be necessary if the peak particle velocity for various structures is below the suggested value and if the Consulting Engineer is satisfied that no damage is expected to occur:

Structure	**Peak particle Velocity (PPV) [mm/s]**	**Frequency (Hz)**
Heritage Buildings	2-3	All frequencies
Residential Buildings	5	All frequencies
Commercial Buildings	8	All frequencies
Buried Services	8	All frequencies