# GEOTECHNICAL GUIDELINES

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## 1. Introduction

Metropolitan conveyance system, as defined below, is very sensitive to deformation and loading. Thus, its protection is of paramount importance to Metropolitan and any projects that occur in the vicinity or over it require a high level of technical analysis and review to ensure there are no adverse impacts to it compromising the continuity and reliability of the Metropolitan conveyance system. As such, the purpose of Geotechnical Guidelines is to provide a brief outline of the work to be performed to evaluate and determine the adverse impacts, if any, of various stages of project development on the structural integrity of the conveyance system. The guidelines require performing geotechnical/geological exploration and engineering analyses, providing geotechnical recommendations, and producing reports. Please note that these minimum requirements set forth in the guidelines cannot be expected to cover all possible conditions encountered for proposed developments. Any adverse impacts to the Metropolitan conveyance system, as determined by Metropolitan, will need to be mitigated to the satisfaction of Metropolitan.

## 2. Definition

Metropolitan's tunnels, canals, pipes, siphons, cut-and-cover conduits, and their appurtenant structures (such as transitional structures, manholes, etc.) are called herein as "the conveyance system."

## 3. Geotechnical Exploration and Testing

3.1 Sufficient and complete geotechnical exploration and testing shall be performed to adequately and fully characterize the subsurface ground and groundwater conditions beneath and adjacent to the conveyance system, and to provide suitable geotechnical information and data to substantiate parameters used and analysis/calculations performed, evaluate potential impacts and determine the adverse effects of the development on the impacted reach of the conveyance system.

3.2 The type of subsurface exploration, testing, and sampling methods utilized should be appropriate for the ground and groundwater conditions. Acceptable exploration methods would include hollow-stem auger, rotary wash, air rotary, or bucket-auger drilling, Cone Penetration Testing (CPT), and shallow trenches

and test pits. Sampling methods could include Standard Penetration Tests (SPT), ring samplers, continuous core, and Shelby tube.

3.3 The number and spacing of explorations shall be as needed to provide the specified subsurface characterization as determined by the complexity and variability of the geotechnical site conditions, or needs of the required geotechnical analysis to be performed. Closely spaced explorations may be necessary if highly variable subsurface conditions are expected or encountered along the impacted reach of the conveyance system affected by the proposed development. Closely spaced explorations may also be needed if subsequent information is needed to complete or perform analyses.

3.4 Exploration shall be drilled/excavated as close as possible to the conveyance system impacted by the proposed development, but no closer than 10 feet to the outside faces of the conveyance system. All exploration methods and locations shall be staked in the field and approved by Metropolitan prior to mobilizing of field exploration equipment.

3.5 Exploration shall be drilled to a depth of at least 5 feet into bedrock or formational material in order to provide adequate information regarding subsurface stratigraphy below the bottom of the conveyance system. In areas of deep underlying bedrock or formational material, the minimum depth of exploration shall be at least 50 feet below the bottom elevation of the conveyance system.

3.6 Disturbed and relatively undisturbed samples shall be collected at a maximum of 5-foot intervals using sampling equipment compatible with the subsurface conditions encountered and the sample types needed for laboratory analyses. Sufficient samples shall be collected to fully and adequately characterize the subsurface conditions and provide enough samples to perform laboratory testing and substantiate soil properties and geotechnical design parameters. Acceptable sampler types would include, but are not limited to, SPT sampler, modified California ring sampler, Shelby tube sampler, Pitcher core sampler, and core barrel. Sampling intervals shall be reduced if more closely spaced data is required for evaluation. In addition to drive samples, bulk samples shall be collected at selected depths for index property testing. A minimum of one bulk sample shall be taken from every subsurface exploration, but consideration should be given to collecting additional samples as appropriate.

3.7 Groundwater depth measurements shall be taken and recorded when groundwater is encountered within subsurface explorations. Explorations shall be left open as required to allow the groundwater level to stabilize. The depth to groundwater shall be measured again, after the groundwater level in the

exploration has stabilized. Both groundwater levels and the time and date of the measurements shall be noted on the exploration logs. For construction or developments that will require dewatering, consideration must be given to the installation of groundwater monitoring wells.

3.8 Geophysical testing methods such as seismic refraction surveys and down-hole (up-hole) tests may be used to supplement exploratory borings and test pits to characterize subsurface conditions, especially to identify the depth to bedrock or formational material. Geophysical testing methods would also be appropriate if highly variable subsurface conditions are anticipated or to better define the subsurface conditions along the impacted reach of the conveyance system.

3.9 Laboratory testing shall be performed on samples collected during the field explorations. The number and frequency of tests performed shall be sufficient to characterize the properties of the earth materials throughout the length of the conveyance system impacted by the proposed development and substantiate the geotechnical parameters utilized in analyses. The type of the tests performed will depend on the type and distribution of the earth materials encountered during field explorations, and the geotechnical input parameter requirements of the analysis needed to be conducted to evaluate potential adverse effects of the proposed development on the impacted reach of the conveyance system. All tests shall be conducted in accordance with industry accepted standards of practice. Appropriate tests would include, but not limited to, in-situ moisture content and dry density, grain size analyses (sieve, or sieve and hydrometer analyses), Atterberg Limits tests, strength testing (direct shear, unconfined compression, and tri-axial), consolidation testing, hydro-consolidation tests (collapse), and maximum dry density testing.

## 4. Required Geotechnical Analysis

Geotechnical analysis shall be required to support all planned development adjacent to the conveyance system. The type of required analysis will depend upon the type of development planned adjacent to or over the conveyance system, and the potential impacts to the conveyance system associated with the planned development. All geotechnical analysis conducted and submitted to Metropolitan shall be performed in accordance with industry accepted methodologies and standard geotechnical practice. Geotechnical analysis submitted shall clearly indicate, identify, and explain all assumptions, methods, procedures, and input parameters used. The results of the geotechnical analysis shall include all calculations and appropriate supporting documentation, and shall fully describe the findings and conclusions of the analysis as these results pertain to the impacted reach of the conveyance system.

Minimum requirements for geotechnical analysis to be submitted to Metropolitan are provided in the following sections, which are classified by the type of development construction. Depending upon the type and extent of proposed development, and the potential adverse affects to the conveyance system, all applicable geotechnical analysis indicated herein shall be provided to Metropolitan for review.

4.1 **Embankments** – The following minimum requirements for geotechnical analysis pertain to all embankments, fills, roadways constructed above and adjacent to the conveyance system, including embankments supported by retaining structures. Four areas of concern associated with embankments shall be addressed by geotechnical analysis.

- Increased load imposed on the affected reach of the conveyance system, both horizontal and vertical under static and dynamic conditions.
- Induced deformation of the affected reach of the conveyance system, both settlement and lateral displacement under static and dynamic conditions.
- Induced instability of the affected reach of the conveyance system under static and dynamic conditions.
- Minimum clearances of installations and constructions.

Minimum requirements for geotechnical analysis and supporting documentation related to embankments are as follows:

4.1.1 Based upon the results of field explorations and laboratory testing, a geologic map shall be prepared of the impacted area of the conveyance system, at a scale appropriate for the project (preferred scale 1 inch = 40 feet). The map shall clearly indicate the location of the proposed development relative to the conveyance system with Metropolitan Station numbers, and the locations of all field explorations (borings, CPT's, testpits, seismic refraction lines, etc.). The geologic map shall also include reference to the vertical datum utilized. Observed geologic contacts, bedding, foliation, clay seams, joints, faults, shear zones, and other relevant geologic information shall be noted on geologic map, as appropriate. The horizontal limits of the geologic map shall extend at least 200 feet normal to, and on both sides of the conveyance system,

and at least 200 feet beyond the limits of the proposed development along the conveyance system.

4.1.2 The proposed grading plan for the development shall also be submitted. This plan shall be prepared at the same scale with the same horizontal limits as the geologic map discussed above, showing both the existing and proposed grading topographic contour lines. The geologic map can be combined with the proposed grading plan provided that the required information can be clearly conveyed in the combined format.

4.1.3 One longitudinal profile along the conveyance system shall be prepared at the same scale as the grading plan, showing the affected reach of the conveyance system with Metropolitan Station numbers. The profile shall show existing grade and proposed finished grade surfaces, groundwater elevation, subsurface elevations and conditions, bedrock elevations, as well as locations of projected field explorations.

4.1.4 Transverse cross-sections normal to the conveyance system shall also be prepared. The transverse cross-sections shall be provided at a minimum spacing of 20-foot on center, referenced to Metropolitan Station numbers of the conveyance system, and shall show all information required above for the longitudinal profile, including scale used. The cross-sections shall also include the embankment location, height and configuration, and its minimum horizontal setback to the conveyance system. Adjustments can be made in the spacing of the transverse cross-sections depending upon the variability of the existing ground or finished grade surface, and subsurface conditions. However, if abrupt, drastic, or sudden changes occur in the conveyance system plan and profile as well as existing ground or proposed finished grade surfaces, and/or the subsurface stratigraphy along the conveyance system, then additional transverse cross-sections shall be prepared at such locations.

4.1.5 Stress analysis using formulas based on the theory of elasticity (such as Boussinesq, Westergaard, etc.) shall be conducted at 10-foot intervals along the impacted reach of the conveyance system to determine the total and incremental loads imposed on the conveyance system by the proposed embankment. The analysis shall consider both vertical and lateral imposed loading on the conveyance system, and shall consider the three-dimensional configuration of the grading for the proposed development and the conveyance system. If the embankment includes a roadway or other sources of traffic loading, the analysis shall include generated live and dead loads. The results of the increased induced-loading shall be presented in both tabular and graphical formats, and

shall present the vertical and horizontal components separately. All results shall be presented relative to the Metropolitan Station numbers of the conveyance system.

4.1.6 Settlement/rebound analysis shall be performed at 10-foot intervals along the impacted reach of the conveyance system to evaluate induced vertical deformation to the conveyance system due to the proposed development. If the embankment includes a roadway, or other sources of traffic loading, the analysis shall include generated live and dead loads. The analysis shall be based on one-dimensional Terzaghi's consolidation theory using representative consolidation test results performed on undisturbed samples collected from the foundation soil, underlying the conveyance system, during the field exploration. The settlement/rebound analysis shall consider the three-dimensional configuration of the grading for the proposed development and the conveyance system, and shall be conducted for points along the conveyance system at least 10 feet beyond both sides of any zero-settlement/rebound points within the impacted reach of the conveyance system. Settlement/rebound analysis due to hydro-consolidation and/or swelling of the foundation soil underlying the conveyance system caused by fluctuation of the groundwater or infiltration of surface water shall be performed. The results of settlement/rebound analysis loading shall be presented in both tabular and graphical formats. The tabular listing of the estimated settlement/rebound shall include the elevations of the bottom of the conveyance system, the alluvium/bedrock contact, groundwater, existing ground surface, and proposed finished grade surface. The table shall present results relative to Metropolitan Station numbers. The graphical representation of the settlement/rebound analysis shall show the estimated settlement/rebound values plotted against Metropolitan Station numbers.

4.1.7 Based on the results of the stress analysis (Item 4.1.5) performed on transverse cross-sections (Item 4.1.4 above), slope stability analysis using Spencer's Method shall be performed on the most critical sections. The critical transverse sections shall be selected in terms of the maximum height of the fill for the proposed development as well as the minimum burial depth of the conveyance system and its minimum horizontal clearance from the toe of the proposed embankment slope. The slope stability analysis on each of the critical sections shall be performed initially for static loading conditions by identifying potential sliding blocks/failure surfaces with minimum factor of safety values that contain the impacted reach of the conveyance system. For each critical section, the identified potential failure plane/failure surface shall be

plotted and labeled with the corresponding calculated static factor of safety and yield acceleration value. If the yield acceleration value for a critical cross-section is equal to, or lower than, the zero period peak horizontal ground acceleration (zero period acceleration = ZPA) discussed under "Seismic Design Criteria," then a seismic deformation analysis using the simplified Makdisi-Seed method shall be performed; a seismic deformation analysis will not be required if the yield acceleration exceeds the ZPA value. The results of the slope stability analysis shall be presented in tabular form. The table shall present the estimated static factor of safety and seismically induced lateral deformation along the corresponding Metropolitan Station numbers for each critical section.

4.1.8 Based on the results of stress, settlement/rebound, and slope stability analyses results, critical sections shall be selected along the impacted reach of the conveyance system to perform more refined deformation analyses under both static and seismic loading conditions. Depending on the configuration of the proposed embankments and its proximity to the conveyance system, two- and/or three-dimensional nonlinear finite element/finite difference analysis shall be performed on the selected critical sections.

The analyses shall consist of three parts: 1) static (gravity) analysis to evaluate initial stresses in the foundation soil, before an input earthquake motion is applied; 2) dynamic analysis to evaluate responses and deformations of the conveyance system to the combination of gravity and the input earthquake motion; and 3) post-earthquake analysis to evaluate deformations of the conveyance system under the gravity load alone, following the effects of earthquake shaking on properties, stresses, and strains within the foundation soil.

The embankment/foundation soil, containing the conveyance system, in the section shall be discretized into homogeneous, isotropic triangular/quadrilateral elements and nodal points, resulting in a finite element/finite difference mesh. Each soil element shall be characterized by its geometry, total unit weight, Poisson's ratio, effective shear strength (cohesion intercept and friction angle), undrained shear strength, residual shear strength (for liquefiable materials), maximum shear modulus, variation of normalized shear modulus with shear strain, and bulk modulus. For cases where soil degradation to a liquefiable or weakened state during or shortly after seismic shaking is required, excess pore water pressure and or/degradation parameters shall also be specified.

The nonlinear behavior of the embankment/foundation soils shall be incorporated in the analysis by an appropriate nonlinear constitutive model representing the nonlinear behavior of the foundation soils under drain and undrained conditions for both static and under the design MCE event. In addition, degradation of shear modulus due to induced shear strain shall be used in both the static and dynamic analyses.

The structures, including piles, shall be modeled by nonlinear beam column elements. Each end of the element, located below the ground surface, shall be either connected to a nodal point or contained in an element in the foundation soil. Young's modulus, section area, moment of inertia, and yield shear and moment shall be specified for each beam element.

For the static analysis, the nodal points located on lateral vertical boundaries of the mesh shall be set on vertical rollers and the nodal points located on the horizontal base of the mesh shall be fixed both in the horizontal and vertical directions.

For dynamic analysis, however, the lateral boundaries shall be connected to transmitting boundaries representing free-field conditions; and the base of the section shall be connected to a compliant base, representing a linear elastic half-space underlying the section. The compliant base prevents the trapping of seismic energy within the discretized system above the base and in effect simulates the application of the input motion at the surface of a hypothetical bedrock outcrop. The properties of the half-space shall be defined by its unit weight and shear wave velocity.

As discussed under "Seismic Design Criteria," an ensemble of acceleration time histories shall be used with normal and reverse polarity as outcropping motions at the compliant base in the time domain nonlinear dynamic analysis. The analysis shall be carried out for a few second (a quiet zone - Part 3) after cessation of shaking to let all excited elements stop vibrating due to viscous damping in the system and lack of the input acceleration.

The above analyses shall be performed for both the existing conditions and the existing conditions with the proposed embankments.

The analysis results will be used to determine the adverse effects of the induced deformations on the structural integrity of the conveyance

system due to the proposed embankments under gravity load as well as during and after the MCE event at the site. If the calculated displacements at a few locations at the conveyance system and the proposed embankments are appeared to be constant and stationary versus time after the cessation of shaking (during the quiet zone - Part 3), the impacted reach of the conveyance system and the proposed embankments will be considered stable, otherwise, unstable and prone to flow slide and total failure. If the difference between the calculated deformations of the conveyance system under the existing conditions and the existing conditions with the proposed embankments are larger than the allowable value for the conveyance system, appropriate mitigation measures to minimize potential geotechnical-related impacts to the conveyance system shall be submitted to Metropolitan for review and approval.

4.2 **Excavations** – The following minimum requirements for geotechnical analysis pertain to large open excavations, both temporary and permanent, made adjacent to the conveyance system, including reinforced slopes. Submittal requirements for shored excavations and pits constructed adjacent to the conveyance system, including permanent retaining walls, are covered in the next section. Three areas of concern associated with excavations shall be addressed by the geotechnical analysis.

- Induced instability of the conveyance system under static and dynamic conditions.
- Induced deformation of the conveyance system, both settlement and lateral displacement under static and dynamic conditions.
- Minimum clearances of installation and construction.

Minimum requirements for geotechnical analysis and supporting documentation related to excavations are as follows:

4.2.1 A geologic map and a proposed grading plan shall be submitted. The requirements for the preparation of the geologic map and grading plan shall be the same as those requirements previously indicated under "Embankments," Items 4.1.1 and 4.1.2.

4.2.2 Transverse cross-sections normal to the conveyance system shall be prepared. The transverse cross-sections shall be provided at a minimum spacing of 20-foot on center, reference to Metropolitan Station numbers

of the conveyance system, and shall show all information previously indicated for the longitudinal profiles, including scale used, under "Embankments," Item 4.1.3. The cross-sections shall also include the excavation location, depth, and configuration, and its minimum horizontal clearance to the conveyance system. Adjustments can be made in the spacing of the transverse cross-sections depending upon the variability of the existing ground or finished grade surface, and the subsurface conditions. However, if abrupt, drastic, or sudden changes occur in the existing ground or proposed finish grade surfaces, and/or the subsurface stratigraphy along the conveyance system, then additional transverse sections shall be prepared at such locations.

4.2.3 Stress analysis using formulas based on the theory of elasticity (such as Boussinesq, Westergaard, etc.) shall be conducted at 10-foot intervals along the impacted reach of the conveyance system to determine the total and incremental loads imposed on the conveyance system by the proposed excavation. The analysis shall consider both vertical and lateral imposed loading on the conveyance system, and shall consider the three-dimensional configuration of the proposed grading for the proposed development and the conveyance system. The results of the increased induced-loading shall be presented in both tabular and graphical formats, and shall present the vertical and horizontal components separately. All results shall be presented relative to the Metropolitan Station numbers of the conveyance system.

4.2.4 Settlement/rebound analysis shall be performed at 10-foot intervals long the impacted reach of the conveyance system to evaluate induced vertical deformation to the conveyance system due to the proposed excavations. The analysis shall be based on one-dimensional Terzaghi's consolidation theory using representative consolidation test results performed on undisturbed samples collected from the foundation soil, underlying the conveyance system, during the field explorations. The settlement/rebound analyses shall consider the three-dimensional configuration of the proposed excavations and the conveyance system, and shall be conducted for points along the conveyance system at least 10 feet beyond both sides of any zero-settlement/rebound points within the impacted reach of the conveyance system. If the alluvium/bedrock contact is not encountered during the field exploration, a minimum alluvial thickness of 50 feet below the invert of the conveyance system shall be considered for the rebound analysis. Criteria for analyzing and presenting the results shall be the same as required for the settlement/rebound analysis under "Embankments," Item 4.1.6.

4.2.5 Based on the results of the stress analysis (Item 4.2.3) on transverse cross-section (Item 4.2.2), slope stability analysis shall be performed on the most critical sections. The requirements for the slope stability analysis shall be the same as the requirements under "Embankments," Item 4.1.7 and "Seismic Design Criteria," except the seismic deformation analysis may not be required per Metropolitan's approval for temporary excavations/cut slopes.

4.2.6 If reinforced slopes (soil nails, soil anchors, and rock anchors) are proposed, transverse cross-sections normal to the face of the slope shall be prepared and complete design calculations shall be submitted. The transverse cross-sections shall be prepared as required in Item 4.2.2 above. The design calculations shall clearly indicate all loading conditions considered and design parameters utilized, and shall include stability analyses demonstrating both internal and external stability of the reinforced slope system, as well as global stability. Calculations shall also be submitted to substantiate nail/anchor design. The seismic design of all permanent reinforced slope systems shall incorporate Metropolitan's "Seismic Design Criteria," except the seismic design may not be required per Metropolitan approval for temporary slope systems.

4.2.7 For all excavations and based on the results of stress, settlement/ rebound and slope stability analyses results, critical sections shall be selected along the impacted reach of the conveyance system to perform refined deformation analyses under both static and seismic loading conditions. Depending on the configuration of the proposed excavation and its proximity to the conveyance system, two- and/or three-dimensional nonlinear finite element/finite difference analyses shall be performed on the selected critical sections. The requirements for the deformation analyses shall be the same as the requirements under "Embankments," Item No. 4.1.8, except the seismic deformation analysis may not be required per Metropolitan approval for temporary excavations/cut slopes. The above analyses shall be performed for both the existing conditions and the existing conditions with the proposed permanent excavations.

The analysis results will be used to determine the adverse effects of the induced deformations on the structural integrity of the conveyance system due to the proposed excavations under gravity load as well as during and after the MCE event at the site. If the calculated displacements at a few locations at the conveyance system and the proposed excavations are appeared to be constant and stationary versus

time after the cessation of shaking (during the quiet zone - Part 3, Item 4.1.8), the impacted reach of the conveyance system and the proposed excavations will be considered stable, otherwise, unstable and prone to flow slide and total failure. If the difference between the calculated deformations of the conveyance system under the existing conditions and the existing conditions with the proposed excavations are larger than the allowable value for the conveyance system, appropriate mitigation measures to minimize potential geotechnical-related impacts to the conveyance system shall be submitted to Metropolitan for review and approval.

4.2.8 If dewatering is required or anticipated to be accomplished as part of the excavation, additional geotechnical submittal requirements shall apply. These requirements are presented under "Dewatering."

4.2.9 In addition to the design information required herein, a description of the proposed sequence of construction shall be submitted for all excavations, including installation and decommissioning of reinforced slope system elements.

4.3 **Shored Excavations/Retaining Walls** – The following minimum requirements for geotechnical analysis pertain to shored excavations and pits constructed adjacent to the conveyance system, including permanent retaining walls. Four areas of concern associated with shoring/retaining structures shall be addressed by the geotechnical analysis.

- Structural integrity of shoring/retaining system under static and dynamic conditions.
- Induced instability of the conveyance system under static and dynamic conditions.
- Induced deformation of the conveyance system, both settlement and lateral displacement, under static and dynamic conditions.
- Minimum clearance of installation and construction.

Minimum requirements for geotechnical analysis and supporting documentation related to shored excavations and retaining walls are as follows:

4.3.1 A geologic map and a proposed grading plan shall be submitted. The requirements for the preparation of the geologic map and grading plan shall be the same as those requirements previously indicated under "Embankments," Items 4.1.1 and 4.1.2.

4.3.2 Where shoring/retaining walls are proposed, transverse cross-sections normal to the face of the shoring/retaining wall shall be prepared. The transverse cross-sections shall be provided at a minimum spacing of 20 feet on center, reference to Metropolitan Station numbers of the conveyance system, and shall show all information previously indicated for the longitudinal profile, including scale used, under "Embankments," Item 4.1.3. The cross-sections shall also include the location, depth, and configuration of the shoring/retaining walls, and its minimum horizontal clearance to the conveyance system. Adjustments can be made in the spacing of the transverse cross-sections depending upon the variability of the existing ground or finished grade surface, shoring/retaining wall configuration, and the subsurface conditions. However, if abrupt, drastic, or sudden changes occur in the existing ground or proposed finish grade surfaces and/or the subsurface stratigraphy along the conveyance system, then additional transverse sections shall be prepared at such locations.

4.3.3 Complete design calculations shall be submitted. The design calculations shall clearly indicate all loading conditions considered and design parameters utilized. Shoring design shall include calculations indicating the anticipated deformations of the shoring system, and the anticipated deformation of the adjacent supported conveyance system. Calculations for the retaining walls shall include stability analysis demonstrating both internal and external stability of the retaining system, as well as global stability. The seismic design of all permanent retaining systems shall incorporate Metropolitan's "Seismic Design Criteria," except the seismic design may not be required per Metropolitan approval for temporary shoring systems.

4.3.4 If the configuration of the shoring/retaining wall systems includes the use of slopes above the top of shoring/retaining walls, then the analyses requirements for "Excavations" shall also be addressed and submitted.

4.3.5 For shored excavations/retaining walls and based on slope stability analyses results, critical sections shall be selected along the impacted reach of the conveyance system to perform more refined deformation analyses under both static and seismic loading conditions. Depending on the configuration of the proposed development and its proximity to

the conveyance system, two- and/or three-dimensional nonlinear finite element/finite difference analyses shall be performed on the selected critical sections. The requirements for the deformation analyses shall be the same as the requirements under "Embankments," Item No. 4.1.8, except the seismic deformation analysis may not be required per Metropolitan approval for temporary shored excavations/retaining walls. The above analyses shall be performed for both the existing conditions and the existing conditions with the proposed retaining walls.

The analysis results will be used to determine the adverse effects of the induced deformations on the structural integrity of the conveyance system due to the proposed shored excavations/retaining walls under gravity load as well as during and after the MCE event at the site. If the calculated displacements at a few locations at the conveyance system and the proposed development are appeared to be constant and stationary versus time after the cessation of shaking (during the quiet zone - Part 3, Item 4.1.8), the impacted reach of the conveyance system and the proposed shored excavations/retaining walls will be considered stable, otherwise, unstable and prone to flow slide and total failure. If the difference between the calculated deformations of the conveyance system under the existing conditions and the existing conditions with the proposed shored excavations/retaining walls are larger than the allowable value for the conveyance system, appropriate mitigation measures to minimize potential geotechnical-related impacts to the conveyance system shall be submitted to Metropolitan for review and approval.

4.3.6 In addition to the design information required herein, a description of the proposed sequence of construction shall be submitted for all shoring/retaining systems, including installation and decommissioning of temporary shoring.

4.4 **Structures** – The following minimum requirements for geotechnical analysis pertain to all structures constructed above or adjacent to the conveyance system, including pile supported structures. Three areas of concern associated with structures shall be addressed by the geotechnical analysis.

- Increased load imposed on the conveyance system, both vertical and lateral under static and dynamic conditions.

- Induced deformation of the conveyance system, both settlement and lateral displacement under static and dynamic conditions.

- Minimum clearances of installation and construction.

Minimum requirements for geotechnical analysis and supporting documentation related to structures are as follows:

4.4.1 A geologic map and a proposed grading plan shall be submitted. The requirements for the preparation of the geologic map and grading plan shall be the same as those requirements previously indicated under "Embankments," Items 4.1.1 and 4.1.2.

4.4.2 The proposed structure layout plan shall be submitted. This plan shall be prepared at the same scale as the grading plan and shall clearly show the locations and dimensions of proposed structures and their foundations, including pile foundations, relative to the conveyance system. Structural foundation plans clearly indicating foundation configurations, depths, and widths shall also be submitted.

4.4.3 Longitudinal and transverse cross-sections as required under "Embankments," Items 4.1.3, and 4.1.4, shall be prepared. These profile and sections shall clearly show the locations, depths, and configuration of proposed structures, and their minimum vertical and horizontal clearances to the conveyance system.

4.4.4 Settlement/rebound analysis shall be performed at 10-foot intervals along the impacted reach of the conveyance system to evaluate induced vertical deformation to the conveyance system by structural loads. The settlement/rebound analysis shall be performed and reported as indicated under "Embankments," Item 4.1.6.

4.4.5 Stress analysis shall be conducted at 10-foot intervals along the impacted reach of the conveyance system to determine the total and incremental loads imposed on the conveyance system by the proposed structures. The analysis shall consider both vertical and laterally imposed live and dead loads. In the case of pile foundations, the analysis shall include lateral pile analysis as well as determination of dragdown/uplift forces. The results of the increased induced-loading shall be presented in both tabular and graphical formats, and shall present the vertical and horizontal component separately. All results shall be presented relative to Metropolitan's Station numbers of the conveyance system.

4.4.6 Lateral deformation analysis shall also be performed at 10-foot intervals along the impacted reach of the conveyance system to evaluate induced

4.4.7 Based on the stress, deformation, and settlement/rebound analysis results, critical sections shall be selected along the impacted reach of the conveyance system to perform more detail and accurate deformation analyses under both static and seismic loading conditions. Depending on the configuration of the proposed structure and its proximity to the conveyance system, two- and/or three-dimensional nonlinear finite element/finite difference analyses shall be performed on the selected critical sections. The requirements for the deformation analyses shall be the same as the requirements under "Embankments," Item 4.1.8. The above analyses shall be performed for both the existing conditions and the existing conditions with the proposed structures.

The analysis results will be used to determine the adverse effects of the induced deformations on the structural integrity of the conveyance system due to the proposed structures under gravity load as well as during and after the MCE event at the site, as discussed under "Seismic Design Criteria." If the calculated displacements at a few locations at the conveyance system and the proposed structures are appeared to be constant and stationary versus time after the cessation of shaking (during the quiet zone – Part 3, Item 4.1.8), the impacted reach of the conveyance system and the proposed structures will be considered stable, otherwise, unstable and prone to flow slide and total failure. If the difference between the calculated deformations of the conveyance system under the existing conditions and the existing conditions with the proposed structures are larger than the allowable value for the conveyance system, appropriate mitigation measures to minimize potential geotechnical-related impacts to the conveyance system shall be submitted to Metropolitan for review and approval.

4.4.8 In addition to the design information required herein, if pile foundations are part of the structural design, a description of the proposed construction methods shall be submitted, which shall include provisions, as necessary, for unstable or caving ground conditions, and groundwater.

4.5 **Dewatering** – The following minimum requirements for geotechnical analysis pertain to dewatering required for development adjacent to the conveyance system, including temporary construction dewatering. Two areas of concern associated with dewatering shall be addressed by the geotechnical analysis.

- Effectiveness of dewatering system.

- Dewatering-induced settlement of the conveyance system.

Minimum requirements for geotechnical analysis and supporting documentation related to dewatering are as follows:

4.5.1 The proposed dewatering plan shall be submitted. The plan shall include a description of the proposed dewatering system, as well as a drawing showing the layout and location of the system. This drawing shall be prepared at the same scale as the grading plan and other applicable development plans, and shall clearly show the locations of the dewatering systems elements, and the locations and dimensions of the proposed excavation/features that require the dewatering relative to the conveyance system.

4.5.2 Transverse cross-sections normal to the conveyance system shall be prepared at locations where dewatering systems are proposed. Transverse cross-sections shall be provided as required to illustrate the location and configuration of the excavation and proposed dewatering system, and shall show all information previously indicated for transverse profiles, including scale used, under "Embankments," Item 4.1.4. The cross-sections shall include the location, depth, and configuration of the excavation requiring dewatering, and its minimum horizontal clearance to the conveyance system. The sections shall show existing grade and proposed finished grade surfaces, subsurface elevations and conditions, as well as locations of projected field explorations.

4.5.3 One longitudinal profile along the conveyance system shall be prepared at the same scale as the grading plan, showing the affected reach of the conveyance system with Metropolitan Station numbers. The profile shall illustrate the location and configuration of the excavation and proposed dewatering system, and shall show all information previously indicated for the longitudinal transverse profile, including scale used, under "Embankments," Item 4.1.3. The profile shall show existing grade and proposed finished grade surfaces, subsurface elevations and conditions, as well as locations of projected field explorations.

4.5.4 Calculations supporting the basis for the dewatering plan shall be submitted. These calculations shall provide the basis for the depth, diameter, and number of dewatering wells, and shall include the anticipated drawdown analysis, including the methods, assumptions,

and parameters used for this determination. The results of the anticipated drawdown analysis shall be graphically, showing the projected lowered groundwater surface relative to the conveyance system using both longitudinal and transverse cross-sections.

4.5.5 The means and methods that will be used to monitor and verify the dewatering operation shall be provided, including the location of proposed monitoring wells.

4.5.6 Details shall be provided for all dewatering wells and monitoring wells used in the dewatering systems. Submitted information shall include, but not limited to, diameter and depth of wells, pipe size and slot configuration, and backfill types and configuration.

4.5.7 Analysis shall be conducted to evaluate dewatering-induced settlement of the affected reach of the conveyance system caused by dewatering operation, which will depend on the magnitude of the drawdown and the extent of the cone of depression. The settlement analyses shall be conducted and presented in accordance with the requirements indicated under "Embankments," Item 4.1.6.

**4.6** **Trenchless Utility Installations:** The following minimum requirements for geotechnical analysis pertain to utility lines being installed adjacent and parallel to, or beneath the conveyance system using trenchless methods of construction, such as jacked casing, horizontal directional drilling, or micro-tunneling. Two areas of concerns associated with the installation of utility lines parallel and adjacent to and beneath the conveyance systems shall be addressed by the geotechnical analysis:

- Stability of excavation and its effect on stability/settlement of the conveyance system
- Effect of shoring system on the conveyance system

Minimum requirements for geotechnical analysis and supporting documentation related to trenchless utility installation adjacent to or beneath the conveyance systems are as follows:

4.6.1 A description of the proposed methods and equipment to be used for the installations shall be submitted. The description shall include, but not limited to, methods, procedures, and construction sequencing or

underground mining and excavation, underground excavation support, utility installation within excavation, grouting and backfilling, and protection and support of adjacent features including the conveyance system. The description shall also include installation sizes and dimensions as well as the maximum grout pressure for each foot of ground cover, the maximum grout pressure, and how the grouting pressure shall be controlled so as to avoid displacing and squeezing the ground overlying the jack casing. The proposed methods and procedures for underground mining and excavation shall be compatible with the anticipated ground conditions, and shall include appropriate provisions to maintain and control the stability of the excavation face to prevent loss of ground in advance of the underground excavation. Additionally, if the anticipated ground conditions exhibit characteristics associated with running or flowing ground, a contingency plan to handle such unstable ground shall be provided.

4.6.2 Plans of the proposed trenchless utility installations shall be submitted showing the location and configuration of the installation. This drawing shall be prepared at the same scale as the grading plan and other applicable development plans, and shall clearly show the locations of the utility installation, and the locations and dimensions of the proposed excavations/pits that will be used for the installation relative to the conveyance system.

4.6.3 Transverse cross-sections normal to the conveyance system shall be prepared at locations where the trenchless utility installations are proposed. Transverse cross-sections shall be provided as required to illustrate the location and configuration of the installation, and shall show all information previously indicated for transverse profiles, including scale used, under “Embankments,” Item 4.1.4. The cross-sections shall include working/receiving pit locations, depths, and the minimum vertical/horizontal clearances from the conveyance system.

4.6.4 Calculations shall be submitted to support the proposed trenchless utility installation. These calculations shall include, but not limited to, structural capacity of all casing and other underground excavation support elements, and required jacking/tunneling pressures. For the case of utility installation underneath the conveyance system, analyses shall be submitted evaluating load transfer from a jacked casing/ directional bore/micro-tunnel via skin friction onto the conveyance system.

4.6.5 Geotechnical analysis requirements previously indicated for shored excavation/retaining walls shall be submitted for all shored excavations and shoring systems required in conjunction with the trenchless utility installation. The required shoring calculations shall also demonstrate that the proposed shoring system can resist anticipated loads imposed onto the shoring from jacking or tunneling activities.

4.6.6 If dewatering is required or anticipated as part of the trenchless utility installation, the analyses requirements indicated under the "Dewatering" shall be submitted.

## 5. Seismic Design Criteria

The following briefly describes Metropolitan's seismic design criteria shall be used to evaluate the adverse impacts, if any, of the proposed development on the structural integrity of the conveyance system.

5.1 Metropolitan's seismic design criteria are in accordance with the IBC 2009. The criteria entail determining an earthquake magnitude and developing a horizontal acceleration response spectrum at 5 percent damping. Based on the IBC 2009, the response spectrum shall be based on both probabilistic seismic hazard analysis (PSHA) and deterministic seismic hazard analysis (DSHA). The PSHA results shall represent a seismic event with an average return period of about 2500 years (2 percent probability of exceedance in 50 years). The DSHA results shall be based on the median (50 percentile) acceleration from the controlling fault multiplied by 1.5. The controlling fault and its maximum considered earthquake (MCE) shall be determined. The maximum considered earthquake (MCE) shall be the smaller of the probabilistic earthquake (2 percent probability of exceedance in 50 years based on PSHA) and deterministic earthquake (1.5x median based on DSHA).

5.2 For performing the site-specific PSHA and DSHA, at least the three of the most current appropriate attenuation relationships shall be selected and average acceleration values shall be used to establish a site-specific response spectrum at 5 percent damping. The attenuation relationships shall represent the subsurface condition at the site and the rupture mechanism (style of faulting) of the controlling fault(s). The DSHA and PSHA acceleration values shall be compared and the lower ones shall be selected as a design response spectrum at 5 percent damping. Please note that if the proposed development cross or run parallel and close to the conveyance system with varying distances to the controlling faults, a site-specific design response spectrum shall be developed

and submitted to Metropolitan for review and approval for each segment along the impacted reach of the conveyance system.

5.3 At least three horizontal acceleration time histories shall be developed for use in time-domain nonlinear dynamic analysis for each segment. The design response spectrum at each segment shall be used as the target for the spectral adjustment of the selected recorded time histories. The design response spectrum shall be in accordance with Items 5.1 and 5.2 above. Development of the acceleration time histories for the project site shall entail the following:

- At least three "seed" time histories shall be selected based on the earthquake event controlling either PSHA or DSHA shaking conditions at the site, namely a moment magnitude from the controlling fault and its closest distance to the site. Other criteria which shall be used as guidance in the selection of the seed recorded time histories are:

    1) the subsurface condition at the recording station shall be similar to that of the site, and

    2) the rupture mechanism (strike-slip, thrust, etc.) shall be similar to that of the controlling fault for the site.

- The response spectra of the selected three seed time histories shall be plotted along with the design response spectrum at 5 percent of damping.

- The selected recordings shall be modified in regard to the frequency content and amplitude so that the resulting response spectra shall generally follow the spectral shape and amplitudes of the target response spectrum.

- The modified time histories shall be base-line corrected such that at the end of the earthquake acceleration, velocity, and displacement values shall be all zero.

- Each base-line corrected acceleration time history along with its velocity and displacement time histories shall be plotted separately on one sheet.

- The response spectra of the base-line corrected acceleration time histories shall be plotted along with the design response spectrum at 5 percent of damping on one sheet.

## 6. Monitoring of Adjacent Conveyance System

**Excavation**: When the conveyance system is near a proposed excavation, it shall be monitored before, during, and after the proposed excavation to document any vertical and horizontal movements of the conveyance system due to the proposed excavation. A land surveyor shall monitor the conveyance system at the start and end of each workday on a daily basis during excavation or installation of shoring systems. Monitoring shall be performed at the same time(s) everyday that monitoring is performed. Interpreted survey data shall be made available to Metropolitan within 12 hours after readings are taken. The frequency of measurements shall be doubled or otherwise modified, as directed by Metropolitan, when measurements exceed the threshold values specified by Metropolitan's Pipeline and Facility Design Team. The land surveyor shall immediately notify Metropolitan of any reading exceeding the threshold values. If excessive movement is taking place, the contractor shall modify construction and support procedures, as approved by Metropolitan, to minimize additional ground or shoring system displacement.

The results of measurements shall be tabulated. A report shall be prepared to tabulate the measured displacement levels. The report shall also include information such as measurement location, date, and depth of excavation. The highest measured displacement levels at each point and their relationship to the threshold values shall also be included in the report.

**Pile/Sheetpile Driving Operation**: When the conveyance system is near a proposed pile/sheetpile (hereon is called "pile") driving operation, it shall be monitored before and during the proposed operation to document any measured peak particle velocity (ppv) at and close to the conveyance system. The monitoring system shall be capable of measuring ppv and frequency level as low as 0.009 in/sec and 0.5 Hz, respectively. The energy transferred to the pile by a hammer, hammer stroke and blow rate, the pile displacement, and both compressive and tensile stresses on the pile shall be simultaneously measured during vibration monitoring as a function of time using either a Saximeter or preferably a Pile Driving Analyzer (PDA). The vibration monitoring system shall undergo certified laboratory calibration conformance at least once a year. And at the time of measurement the vibration monitoring system shall have a certificate that is not expired.

For underground conveyance system (such as pipes, cut-and-cover conduits, and siphons) a downhole waterproof seismograph (e.g., a downhole three dimensional seismograph calibrated to measure ground velocities) shall be installed on the centerline of the conveyance system a maximum of 2 feet above its crown; and three seismographs shall be deployed and positioned on the existing ground surface at zero, 5, and 10 feet intervals from the centerline of the conveyance

system toward the pile being driven. If the conveyance system is at the ground surface (such as canals or transition structures) two seismographs shall be installed next to its concrete lining on both sides; and three seismographs shall be deployed and positioned on the existing ground surface at 5, 10, and 15 feet intervals from the edge of the canal closes to the pile being driven.

The seismographs shall be placed on a straight line normal to the axis of the conveyance system coinciding with the centerline of each pile. These seismographs shall provide ground vibrations at the conveyance system and a few locations at the ground surface to evaluate attenuation of the ground vibrations with distance from the source. The seismographs shall provide the ppv along longitudinal, transverse, and vertical directions of the conveyance system.

When measurements exceed the threshold values specified by Metropolitan, the person who is responsible for the vibration monitoring and analysis shall immediately notify Metropolitan of any ppv reading exceeding the threshold values. If excessive ppv is taking place, the contractor shall modify construction and support procedures, as approved by Metropolitan, to minimize additional ground or shoring system displacement.

The results of measurements shall be tabulated. A report shall be prepared to tabulate the measured vibration levels at the three axes and the associated frequencies. The report shall also include information such as measurement location, date, and source of vibration. The highest measured vibration levels for each axis and their relationship to the threshold values shall also be included in the report.

## 7. Report Requirements

The required geotechnical exploration, testing, and analysis shall be submitted in a formal report/letter for Metropolitan's review. The presented geotechnical information shall be consistent with project plans and specifications. Geotechnical information submitted shall be signed, stamped and prepared under the supervision of either a Civil or geotechnical Engineer registered in the State of California, and when applicable, a Registered Geologist or Engineering Geologist, registered in the State of California.

Calculations supporting geotechnical design shall be signed and stamped by either a Civil, Geotechnical, or Structural Engineer registered in the State of California. All geotechnical parameters used in support of calculations shall be clearly referenced and substantiated by the performed geotechnical exploration and testing. Structural calculations do not need to be included as part of submitted

geotechnical reports, but sufficient documentation shall be provided with the calculations to identify their purpose and place within a development submittal.

All methods and procedures used for geotechnical analysis, including computer programs, shall be clearly described, referenced, and documented. All assumptions and limitations of analyses shall be fully explained. Results developed by computer programs shall include all input and output data generated, adequately annotated to fully explain the results.

Geotechnical reports/letters shall be logically organized to convey the required information, and shall be prepared as stand-alone documents. Geotechnical reports/letters shall be prepared as concisely as possible, but shall completely describe the explorations, tests, and analyses conducted. Geotechnical reports shall also clearly describe the geotechnical site conditions, and shall state the results of the conducted geotechnical work performed and discuss the potential geotechnical impacts associated with the proposed development on the conveyance system. A discussion as to how the proposed development will impact or not impact the affected conveyance system shall also be included. Geotechnical reports shall provide recommendations for additional geotechnical studies or potential mitigation measures to minimize potential geotechnical-related impacts to the conveyance system, as appropriate for the findings of the geotechnical work preformed.