5 Update to Existing Environmental Conditions

Following the establishment of existing conditions for the Study Area, more detailed analyses were conducted to further inform and develop the subsequent evaluation criteria and evaluation of alternative designs discussed in **Section 6**.

5.1 Natural Environment Focused Field Studies

An extensive natural environment focused field study program was undertaken. The complete report can be found in **Appendix B.** Natural environment field surveys were conducted as part of this update to existing conditions and included:

- Ecological Land Classification (ELC);
- Significant Wildlife Habitat (SWH) assessment;
  - Amphibian breeding surveys;
  - Breeding bird surveys;
  - Bat maternity colony habitat assessment;
- Significant Woodlands assessment;
- Canadian Wetland Classification;
- Aquatic features assessment; and,
- Species at Risk (SAR) habitat suitability analysis.

Conducting these surveys was limited to areas where consent to enter was obtained during the appropriate timing window for each field survey.

5.1.1 ECOLOGICAL LAND CLASSIFICATION

Twenty-five natural vegetation communities were documented within the Study Area following the established methodology as per the *ELC system for southern Ontario* (Lee et. al., 1998) with updates from the 2008 catalogue. No ELC vegetation communities were found to be provincially at risk or of conservation concern as per the Natural Heritage Information Centre (NHIC). A total of 93 vascular plant species were recorded and most plants inventoried are common to widespread throughout Ontario. Vegetation SAR observed included City of Ottawa's compensation plantings of Butternut (*Juglans cinerea*) specimens (listed as Endangered both federally and provincially) within the existing Transitway corridor, north and south of Berrigan Drive and Black Rapids Creek corridor (not considered compensation plantings). Detailed ELC mapping is found in **Appendix B.**

5.1.2 SIGNIFICANT WILDLIFE HABITAT

There are four categories of SWH: seasonal concentration areas, migration corridors, rare or specialized habitats and Species of Conservation Concern. Species and their habitats that are already protected as Endangered or Threatened under the ESA are not considered in the assessment of SWH.

Three candidate SWH features and three confirmed SWH features were identified within the Study Area (**Table 5-1**). There are no candidate or confirmed migration corridors for the Study Area. Candidate SWH refers to those natural features that are potentially significant based on the presence of suitable habitat in the criteria outlined in MNRF's SWH guidance document (2015).

All candidate and confirmed SWH features were identified based on ELC, wildlife habitat assessments, and targeted surveys.

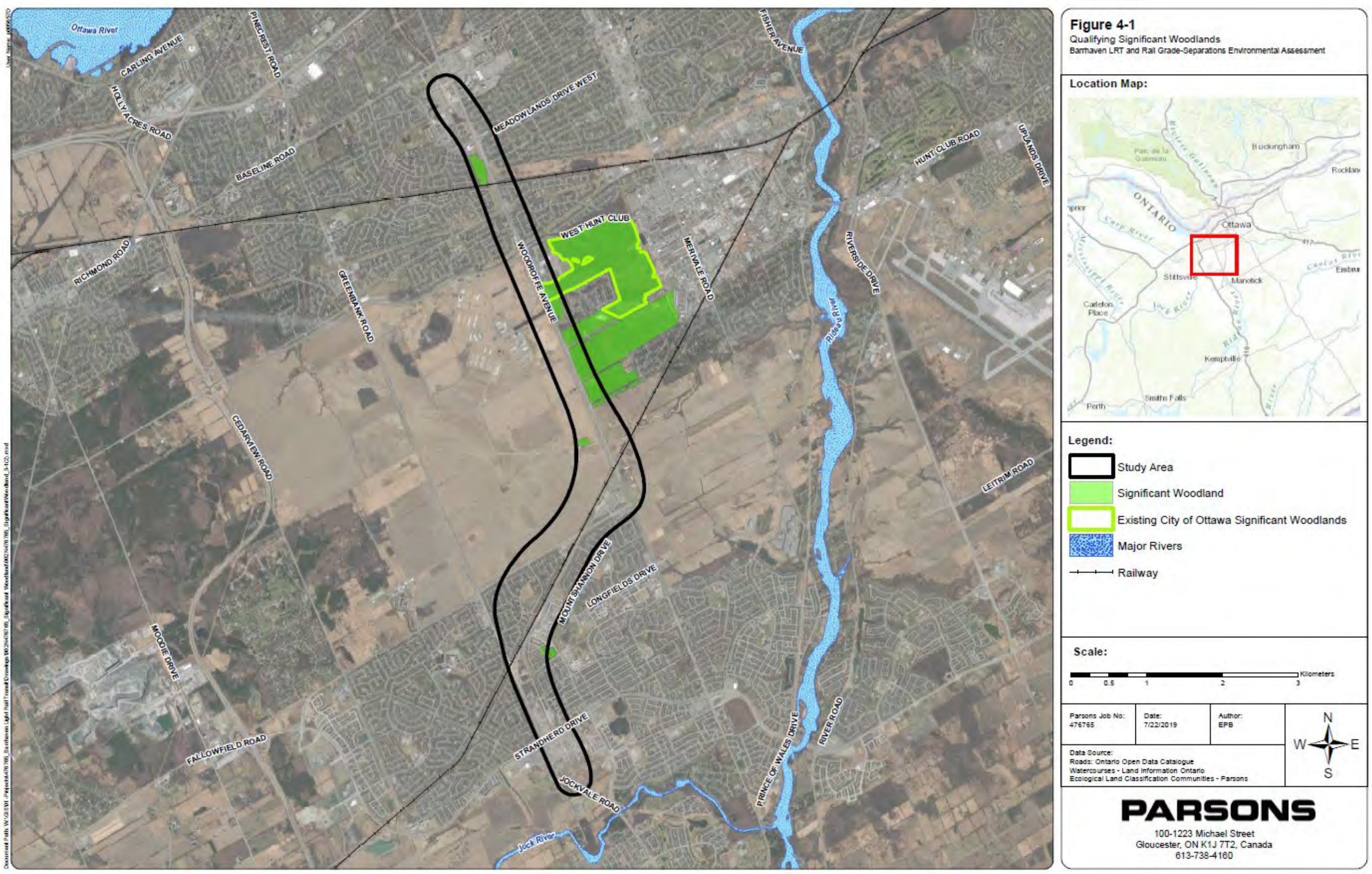
Table 5-1 Summary of Candidate and Confirmed SWH for the Study Area

SWH Category	Wildlife Habitat	Determination
Seasonal Concentration Areas	Waterfowl stopover and staging areas (terrestrial)	Candidate
	Bat Maternity Colonies	Candidate
Rare Habitats	Sand Barren	Confirmed; natural feature SBOB1
Specialized Habitats	Woodland raptor nesting habitat	Confirmed; a breeding pair of Cooper's Hawk observed in the forest communities of Pinhey Forest
	Amphibian breeding habitat (wetlands)	Candidate
Habitats for Species of Conservation Concern	Special Concern and Rare Wildlife Species	Confirmed; breeding pairs of Eastern Wood-pewee were observed within the forest communities comprising Pinhey Forest

5.1.3 SIGNIFICANT WOODLANDS

An assessment was conducted to determine if there were additional qualifying areas within the Study Area that meet the criteria for significant woodlands. Existing and qualifying significant woodland areas were identified as illustrated in **Figure 5-1**.

Figure 5-1 Significant Woodland Assessment Results



5.1.4 SPECIES AT RISK

Following additional field surveys including targeted surveys, the following is applicable to the Study Area:

- Four Threatened/Endangered species under the ESA and/or SARA were confirmed present within the Study Area, these include: Butternut, Barn Swallow, Bobolink and Eastern Meadowlark.
- One species, Eastern Wood-pewee, listed as special concern species under the ESA and SARA was confirmed present within the Study Area.
- Seven Threatened/Endangered species under the ESA and/or SARA have a high potential to occur within the Study Area, these include: Bank Swallow, Chimney Swift, Common Nighthawk, Wood Thrush, Little Brown Myotis, Northern Myotis and Tricolored Bat.
- Seven species listed as Special Concern under the ESA and/or SARA have potential to occur within the Study Area, these include: Monarch, Yellow-banded Bumble Bee, Snapping Turtle, Eastern Milksnake, Evening Grosbeak, Grasshopper Sparrow and Northern Brook Lamprey.

5.1.5 CANADIAN WETLAND CLASSIFICATION

Classification keys outlined in the Canadian Wetland Classification System were utilized to determine wetlands within the Study Area (NWWG 1997). Wetlands are classified based on three levels: class, form, and type.

In total, five wetlands were identified to occur within the Study Area, according to the ELC system. These vegetation units have been further evaluated based on the federal wetland guidelines. Wetland classification, description and locations of the evaluated wetlands identified based on their associated ELC code are provided (Table 5-2). The wetland communities observed within the Study Area are common throughout Ontario and have been heavily influenced by adjacent land uses i.e. active agriculture, transportation corridors, or pine plantations.

Table 5-2 Canadian Wetland Classification for the Study Area

ELC Vegetation Type	Wetland Class	Wetland Form	Wetland Type
SWDM3-2 Silver Maple Mineral Deciduous Swamp	Mineral Swamp[1]	Discharge Seepage Swamp[3]	Hardwood Treed[6]
SWDM4 Mineral Deciduous Swamp (Black Rapids Creek)	Mineral Swamp[1]	Riverine Swamp[4]	Hardwood Treed[6]
SWTM5 Mineral Deciduous Thicket Swamp (Black Rapids Creek, shown as MAMM1/SWTM5)	Mineral Swamp[1]	Riverine Swamp[4]	Mixed Shrub[7]
MAMM1 Graminoid Mineral Meadow Marsh (Black Rapids Creek, shown as MAMM1/SWTM5)	Mineral Marsh[2]	Riparian Stream Marsh[5]	Graminoid (Grass and Tall Rush)[8]
MAMM1-12 Common Reed Graminoid Mineral Meadow Marsh	Mineral Marsh[2]	Riparian Stream Marsh[5]	Graminoid (Reed – dominated by reed species (*Phragmites spp.*)

[1] periodically standing surface water and gently moving, nutrient-rich groundwater, with vegetation dominated by woody plants > 1 m high.

[2] wetland ecosystem characterized by minimal or no peat accumulation (although thin layers of muck and a mix of mineral and organic muck may be present), periodic or persistent standing water or slow-moving surface water which is circumneutral to alkaline and generally nutrient-rich, and vegetation dominated by graminoids, shrubs, forbs, or emergent plants.

[3] topographically flat and develop around and along the outflow of groundwater seepage. There are no distinct springs on the surface.

[4] occur along the banks of rivers and permanent/intermittent streams. Water table maintained by the level of water in the adjacent stream. Situated adjacent to streams and subject to flooding.

[5] situated on channels, streams, or rivers, on watercourses with continuous or intermittent flow.

[6] dominated by broadleaf species in the canopy layer. Most common species are maple species (*Acer spp.*), black ash (*Fraxinus nigra*), American elm (*Ulmus americana*), birch species (*Betula spp.*), and balsam poplar (*Populus balsamifera*).

[7] tall shrubs (> 1.5 m), medium shrubs (0.5 to 1.5 m), and low shrubs (0.1 to 0.5 m).

[8] dominated by low, tall, or mixed grass species and cattail species.

5.2 Geotechnical Investigation

To assist with the evaluation of alternative designs a geotechnical program was executed which included two boreholes along with analysis of extensive historical borehole data to provide more detail regarding the subsurface existing conditions and potential constraints. The full report can be found in Appendix B. The results confirm and support the soil and groundwater challenges identified during previous planning studies in the vicinity of the proposed rail grade-separations for Woodroffe Avenue, Southwest Transitway and Fallowfield Road. The results from these investigations identify the same subsurface challenges that exist in the vicinity of the rail grade-separations exist in the north section of the Study Area between Baseline Station and West Hunt Club Road. The subsurface conditions in the southern section of the Study Area were also investigated between Fallowfield Road and Barrhaven Town Centre.

5.2.1 NORTH SECTION - LRT ALTERNATIVES

The north section is underlain by compressible silty clay (up to about 13 m thick), over sand, silt, glacial till and bedrock. An extensive deposit of sand underlies the silty clay, increasing in thickness as the thickness of the silty clay decreases to the south.

The silty clay deposit, where present, has limited capacity to support additional loading without undergoing potentially significant compression, which could in turn lead to settlement of overlying structures. If excessive foundation settlements are to be avoided, the net change in stress on the underlying silty clay must be limited so that the stress level in the silty clay would not approach or exceed the deposit's precondition pressure (i.e., its 'yield' stress). The additional potential stress on the silty clay could result from a combination of new foundations loads, the weight of any material used for filling around the structures and any potential future groundwater level lowering.

5.2.1.1 Elevated Alternatives

Based on the anticipated subsurface conditions encountered between Baseline Station and Knoxdale Road, it is expected that elevated/overpass structures (including the Tallwood Station), if considered along this segment of the LRT alignment, would likely need to be supported on deep foundations supported on the underlying glacial till or bedrock, in order to minimize the additional stress on the silty clay due to the foundation loads or filling. Based on the previous boreholes advanced along this section of the alignment, the depth to the bedrock surface is expected to be in the range of about 12 to 17m, generally decreasing towards south. The use of embankments is not recommended as they would require preloading and generally more technically complicated construction methods. No hydrogeological constraints are anticipated associated with the elevated/overpass structure alternative.

5.2.1.2 Below-Grade Alternatives

Conceptually, construction of the LRT within an open trench or tunnel (either cut and cover on installed by underground tunnelling) is feasible from a geotechnical standpoint but the ground conditions would result in significant risks, mainly related to control of groundwater.

Hydrogeological Considerations

A hydrogeological analysis was carried out for the below-grade alternatives to assess the potential inflows and impacts. Assuming the open excavations would extend to about 1m below the underside of the rail structure, this would be between 5 to 7m below the measured groundwater level. Groundwater inflows from the sandy deposits will be very high and will have significant construction impacts with respect to the excavation and structure. Based on the results of the previous hydrogeological investigations, and depending on the final LRT grades, temporary and permanent groundwater lowering in this area could lead to an unacceptable risk of settlement for the structures, facilities and utilities founded on shallow foundations. The predicted drawdown radius of influence could extend to approximately 250m located in or near the vicinity of the excavation due to the presence of thick compressible silty clay. The settlement impacts will not necessarily be limited to the areas immediately adjacent to the trench.

The steady-state dewatering rate would need to be maintained for the life of the structure, assuming it would remain drained. Alternatively, the structure could be made entirely waterproof such that the groundwater levels could return to their current levels following construction. This would, however, significantly complicate the construction of the underground structure and potentially the long-term maintenance (because of the need to maintain extensive waterproofing, liners, seals, etc.).

Open Cut Trench or Tunnel Considerations

The clay settlement mechanism described above is currently well understood in the geotechnical engineering community in the Ottawa area. Historically, however, it was not always understood and there have been instances where dewatering has resulted in significant settlements of structures.

In the case of the LRT tunnel/trench, the groundwater levels would need to be lowered permanently, as well as during construction, in order to maintain a dry facility. Typically, where that is required but the risks of dewatering are very high (as in this case) the approach is to carry out the excavation within a watertight shoring system and to design the permanent structure to be watertight, such that permanent pumping of groundwater is not required. This typically requires extremely robust shoring systems, such as interlocking secant pile walls or slurry walls that extend at last a few metres below the bedrock surface to completely cut off water inflows. Construction of a watertight base slab, tied into the watertight shoring on either side is also required.

Construction of watertight shoring and permanent structures is difficult, very costly and is not always successful. There are a number of construction challenges that must be overcome. The secant pile or slurry walls must be constructed in such a manner that the individual piles or slurry wall panels are completely interlocked (i.e., joined without gaps, or ‘windows’) over the full depth of installation. This can be difficult to achieve in practice but has been done successfully on many projects. However, the projects where complete sealing of the shoring has been achieved typically involve relatively limited lengths of shoring or construction areas (such as a building footprint), and typically require significant amounts of localized repairing as excavation proceeds). In the case of the Barrhaven LRT tunnel/trench, the watertight shoring walls and base slab would need to be constructed on both sides and base of the more than 2 km long cut. Achieving the required shoring integrity over that length would be a significant challenge. Where the shoring installation does result in gaps or leakage, the corrective measures are difficult, costly, time-consuming and may not be entirely successful. Those measures typically involve grouting to seal the gaps (which can be very difficult to successfully complete), jet grouting, ground freezing (as a temporary solution), or the installation of recharge systems (which may be required to operate for the life of the facility).

It should also be noted that even small leaks in the permanent structure, especially if there are a number of them, can result in groundwater lowering that may take place over a number of years, resulting in third party claims many years after construction.

Tunnelling (TBM) Considerations

Alternatively, a tunnel or twin tunnels could be constructed using tunneling or trenchless methods along the entire alignment from Baseline Station to West Hunt Club Road. The total length of the alignment is about 2.3 km and a TBM drive (or drives for twin tunnels) of this length may be economically feasible, although still costly, in comparison to the challenges noted above for open cut construction and the potential disruption associated with open cut construction.

TBM tunnelling, however, is not without risk in the ground conditions along this alignment. The ground conditions will change from till, to sands and clays along the alignment. These ‘mixed face’ conditions can be challenging from a tunnelling perspective since it is difficult to appropriately condition the spoils for muck removal and tunnel advancement as the composition of the soil changes. This can lead to clogging, that significantly slows the rate of advancement (resulting increased cost or schedule delays), or, of more concern if support cannot be maintained in the running sands, over excavation and loss of ground can lead to sinkholes that result in damage to structures and utilities and threats to public safety.

In addition, although the risks of settlement of structures founded on compressible clay would likely be minimal for construction of the tunnel, the construction of the stations would still require watertight shoring, as described above for the open cut trench or tunnel. Permanently watertight structures would also be required for the stations as well and the resulting risks associated with groundwater control as described above for the open cut option, although of lesser magnitude, would still apply for those excavations and the completed structures. Any leakage over time in the tunnel lining (due to construction issues of degradation of the gaskets or liner) could result in groundwater lowering over the long term that could lead to settlement and damage of structures or utilities along the alignment.

5.2.2 RAIL GRADE-SEPARATIONS

The subsurface conditions between West Hunt Club Road and Slack Road generally consist of sandy deposits but the total thickness of the deposits is not known. South of Slack Road, the sandy deposits tend to thin out and compressible silty clay is present with the thickness of the deposit increasing towards the south. Near the VIA Rail crossing, the LRT alignment is generally underlain by compressible silty clay, over very loose to loose silty and sandy soils, above glacial till and bedrock. The surface of bedrock was encountered in the range of 9 to 10m depth at the rail crossing.

It is not considered feasible to support an overpass in this location on shallow foundations given the limited capacity of the compressible silty clay. An overpass structure will therefore have to be founded on deep foundations. There are no significant geotechnical concerns with supporting bridge structures on deep foundations (such as driven steel H-piles end bearing on rock or drilled cast-in-place caissons end bearing on, or socketed in, the bedrock), recognizing that some of the piles could have difficulty penetrating to the bedrock surface and could 'hang up' on cobbles and boulders within the glacial till which overlies the bedrock, if driven steel H-piles are considered.

The significant issue with respect to excavations is groundwater control. Excavations below the groundwater level, which penetrate the overburden soils and are near/in the bedrock surface will experience significant groundwater inflow. Based on a previous pumping test carried out at the Fallowfield Road crossing, the water table in the very permeable bedrock will need to be lowered significantly to complete construction. In addition, based on the results of the previous investigations, the excavations may encounter basal heave and/or soil boiling when the base of excavation is within about 3 or 4m of the bedrock.

Water drawdown in the bedrock would also potentially cause consolidation of the overlying soil due to water depletion in the silty clay and very loose and loose silt material, resulting in settlement of adjacent structures supported on and within the overburden in the area. The magnitude of the consolidation settlement as a result of groundwater lowering is difficult to predict but it is likely greater than what structures can typically tolerate (i.e., greater than 25mm), which would be in addition to any settlement previously experienced by the structures.

Depressurizing the groundwater in the bedrock could prevent basal heave / soil boiling. This option would require continuous pumping of groundwater inflows from the bedrock to recharge wells even after the construction period. In the long-term, however, unless the water table in the bedrock is returned to pre-construction levels, pumping in the bedrock could lower the water in the bedrock regionally resulting in settlements of structures supported on and within the overburden in the area. Furthermore, any excavation that reaches or penetrates bedrock would require placement of low hydraulic conductivity material such as concrete and/or weathered clay to prevent hydraulic connection between the structure base materials and the bedrock.

Based on the above, an overpass bridge structure is considered to be the preferred grade-separation alternative from a geotechnical and hydrogeological perspective.

5.2.3 SOUTH SECTION - BRT TO LRT CONVERSION

The subsurface conditions moving southwards generally consist of silty clay and glacial till. The thickness of silty clay tends to decrease towards Barrhaven Town Centre and is limited or absent between Highbury Park Drive and Jockvale Road. Shallow bedrock was encountered between Highbury Park Drive and Berrigan Drive. The bedrock consists of sandstone underlain by dolostone or limestone.

Near Berrigan Drive, in view of the shallow bedrock conditions (within about 1m depth), a bridge structure, if considered, could be founded on spread footings supported directly on the bedrock. Since the embankments will essentially be supported on bedrock, settlement of the approach embankments will only occur due to compression of the embankment fill itself; settlement of the subgrade should be negligible.

South of Berrigan Drive, the bedrock surface is at deeper depths. Although technically feasible, it would not be practical to support the foundations of the new station on bedrock. The new station could instead be founded on shallow foundations placed directly on glacial till.

Shoring will likely be required due to the space constraints within the Barrhaven Town Centre. The type of shoring will depend on the proximity to existing structures and may require the use of relatively inflexible shoring (e.g., secant piles).

Some groundwater inflow into the excavations should be expected. However, if the floor of excavations will approach or extend into the bedrock surface, inflow from the bedrock would be significant. Some form of active dewatering will be required (such as pumping from a series of wells drilled into the bedrock) and the groundwater level will need to be lowered in advance of excavation; otherwise the rate of groundwater inflow to the excavation would be excessive.

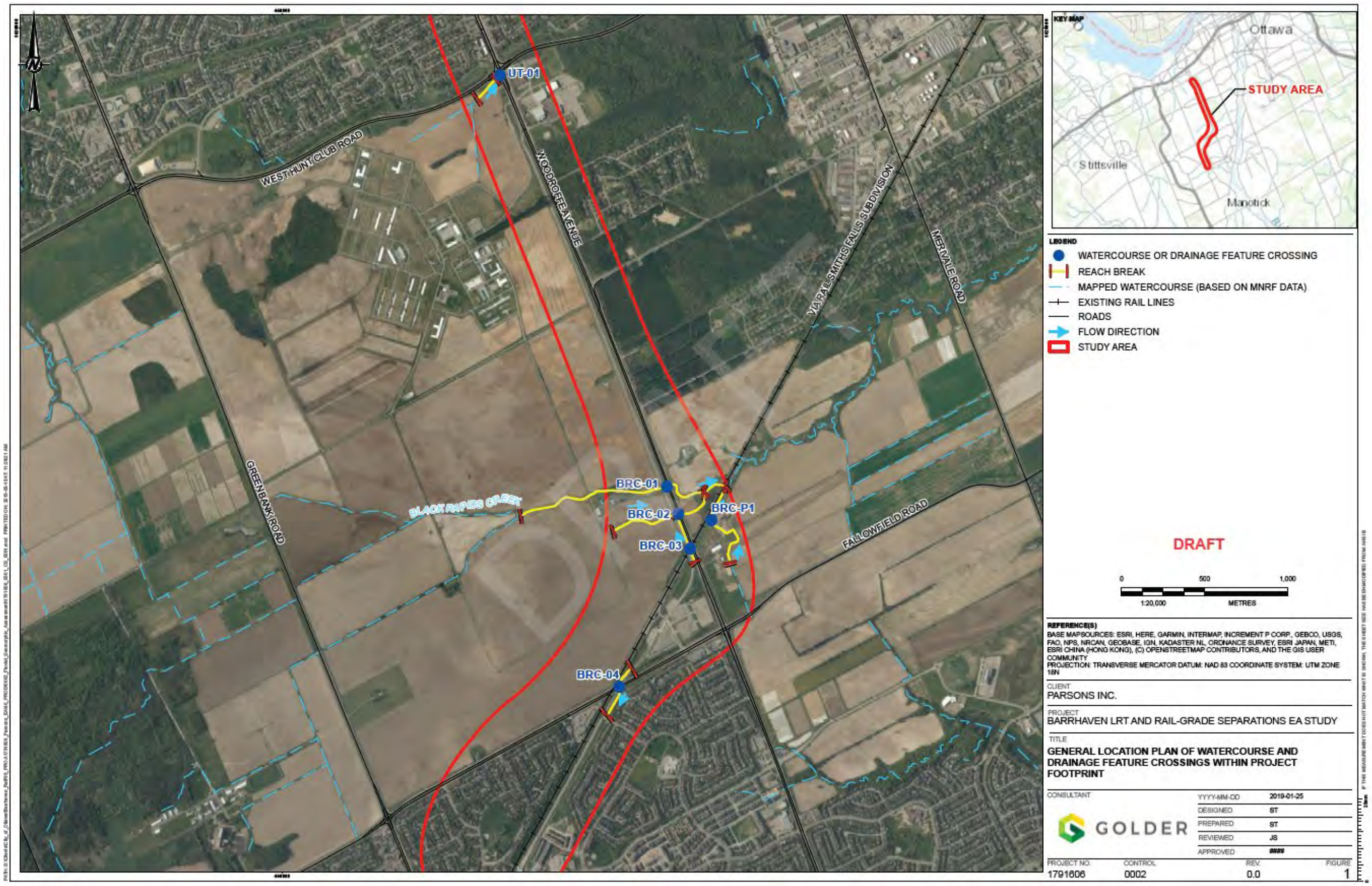
Short-term groundwater level lowering can be expected in the area around the new bridge and/or station due to the groundwater control requirement during construction. Longer-term groundwater level lowering may also be expected if a drainage system beneath and around the below-grade stations and running track is required. The silty clay soils in this area are potentially sensitive to changes in the ground water level. The potential for impacts on surrounding structures and utilities will therefore need to be evaluated.

It is expected that some groundwater lowering has already occurred due to drainage system of the existing underpass structures, which is likely at a similar level to the planned drainage system. The additional drawdown resulting from construction will therefore likely be fairly modest. Further, silty clay is not present on the southern section of the alignment. Where present, due to the low hydraulic conductivity of the silty clay (and the underlying glacial till), the drawdown is expected to be fairly localized to the area of construction. It is therefore expected that the potential groundwater level lowering would not cause excessive settlement of existing structures; however, this would need to be confirmed during subsequent geotechnical investigations during preliminary and detailed design.

5.3 Fluvial Geomorphic Assessment

A fluvial geomorphic assessment was conducted on relevant watercourse crossings in the Study Area to determine the extent of the 100-year erosion limit for each channel and thereby inform the functional design of upgraded crossing structures (**Figure 5-2**). The reaches of BRC-01 (Black Rapids Creek), BRC-02 (tributary to Black Rapids Creek) and BRC-P1 (tributary to Black Rapids Creek) are generally characterized by straightened/realigned channel patterns (altered before 1965 to accommodate agriculture or other land use practices) and have shown limited evidence of natural planform adjustment over the duration of the historical air photograph record. These reaches were shown to include no particular channel characteristics that would merit specific crossing structure sizes from the perspective of fluvial geomorphology. It is expected that the minimum span recommendations for the study reaches of BRC-03 (engineered ditch that conveys flows north-south located between the Southwest Transitway and Woodroffe Avenue), BRC-04 (engineered ditch that conveys flows to/from a stormwater management facility) and UTC-01 (tributary to Nepean Creek) will be based on hydraulics alone (i.e., conveyance of the design flood).

Figure 5-2 Location of Watercourse Crossings within the Study Area



5.4 Headwater Drainage Assessment

A headwater drainage assessment was conducted for the Study Area where four sites were observed (**Figure 5-3**). The complete assessment can be found in **Appendix B**. Based on the management recommendations (TRCA, 2014), it was determined that BRC1-ST1, BRC1-ST2, BRC2-ST2, and BRC3-ST1 will require protection. This involves ensuring that the reach remains open and that the hydroperiod is maintained and is directly connected downstream. Relocation of any kind is not permitted and groundwater or wetlands must be maintained.

Conservation was recommended for BRC2-ST1. This involves maintaining or replacing the existing surrounding features, including on-site and external flows and vegetation within the riparian zone corridor. Natural design techniques to maintain or enhance the reach are to be used.

No management is required for both the GRFD1-ST1 site, due to the lack of flow, natural vegetation and connection downstream.

Figure 5-3 Headwater Drainage Feature Assessment Locations and Management Recommendation