Matrix Solutions Inc.
A Montrose Environmental Company

HIDDEN VALLEY SOURCE WATER PROTECTION ASSESSMENT STUDY

Prepared for:
CITY OF KITCHENER

Prepared by:
MATRIX SOLUTIONS INC., A MONTROSE ENVIRONMENTAL COMPANY

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Guelph, Ontario

Unit 7B, 650 Woodlawn Rd. West
Guelph, ON, Canada N1K 1B8
T 519.772.3777 F 226.314.1908
www.matrix-solutions.com

City of Kitchener
Engineering Division
APPROVED

Signature: KatieWo
Date: 01/07/2025

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Prepared for the City of Kitchener, August 2024

Scott Robertson, P.Eng.
Senior Water Resources Engineer

reviewed by
Jeremy Piper, M.Sc.
Senior Director – Eastern Groundwater

DISCLAIMER

Version Control

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1 Introduction

Located in the southeast portion of the City of Kitchener (City), the Hidden Valley Community (the study area) is generally bounded by the Grand River to the south, Wabanaki Drive to the west, a rail corridor / Fairway Road to the north, and Highway 8 to the east.

The Council-approved Hidden Valley Land Use Master Plan (2019; Figure 1) established anticipated development concepts for the approximately 183 ha study area. The most intensive development is anticipated in the north portion of the study area, east of Wabanaki Drive and south of Hidden Valley Road, along the planned River Road Extension and Stage 2 ION light-rail transit (LRT) corridors, and the southwest, adjacent the future roundabout (River Rd. / Hidden Valley Rd. / Wabanaki Dr. / Goodrich Dr.). There is potential for lower-intensity development in the central and eastern areas. Planned land uses in the study area include a range of low-rise residential, medium-rise residential, mixed-use, commercial, and high-rise residential land uses.

As part of a Secondary Planning process, the City is currently undertaking a review and update of the Master Plan, an undertaking that is being informed by a range of technical studies, one of which is this Source Water Protection Assessment (SWPA). The SWPA is required due to the proximity of three Region of Waterloo water supply sources, namely the Fountain Street and Parkway well fields and the raw water surface intake from the Grand River at the Hidden Valley weir. As defined through previous and currently ongoing studies, the associated protection zones associated for each of these sources extend across portions of the Study Area, including anticipated development areas. This SWPA study has been undertaken to document the characteristics of the SWP areas and related policies, assess the potential for impacts on existing systems associated with the implementation of the Secondary Plan, and to provide recommendations for impact mitigation.

2 Study Area Characterization

This section contains a high-level overview of the study area's environmental and source water supply characteristics of potential relevance to the SWPA; it is not intended to represent a comprehensive assessment of the complex hydrology and hydrogeology of the area. There are a number of documents referenced herein, both historic and currently underway, that may provide the interested reader with a more in-depth perspective.

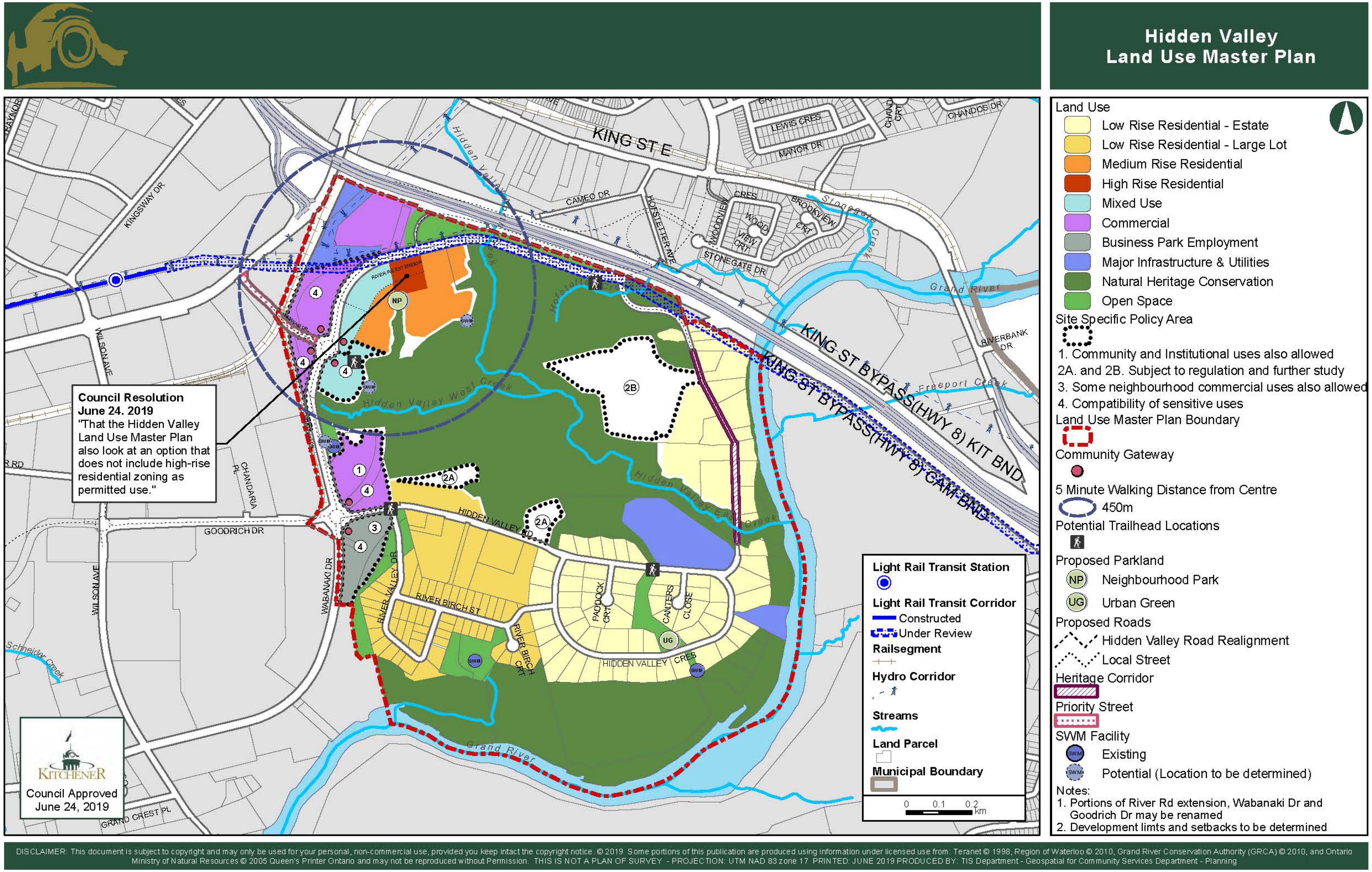

Figure 1 Hidden Valley Land Use Master Plan, Council-Approved (2019)

Existing land uses within the study area itself are generally of low intensity and include numerous agricultural fields, estate lot residential developments (in the southern half of the study area), and substantive natural heritage / environmental features. In contrast, land uses in areas contributing drainage to and through the study area are highly urbanized with commercial/industrial uses to the west and north, with high-and medium-density residential land uses to the northeast, across the Highway 7/8 corridor. Along Hidden Valley Road there are several large lot residential units draining directly to the Hidden Valley ESPA/PSW.

Under existing conditions, the study area is characterized primarily by rolling topography, with elevation differences of more than 50 m between high points at the west / northwest limits and the floodplains adjacent the Grand River. Surficial geology is primarily comprised of coarse materials (gravels / sands) conducive to at-source infiltration with smaller pockets of diamicton around the perimeter.

A west-to-east gravel esker feature bisects the study area, forming the southern edge of a large woodland/wetland complex in the centre of the study area, holds classifications of a Provincially Significant Wetland (PSW), Environmentally Sensitive Policy Area (ESPA), and Core Environmental Feature (CEF). This feature, referred to herein as the Hidden Valley ESPA/PSW, is considered a regionally significant woodland and significant valley, species at risk habitat, a warmwater fishery, and a regionally significant groundwater recharge area.

2.1 Municipal Water Supply Sources

There are three municipal water supply sources within sufficient proximity to the study area that their consideration within the current assessment can be reasonably expected, namely the Hidden Valley Surface Water Intake at the Grand River, the Parkway Well Field, and the Fountain Street Well Field. A brief description of the physical characteristics of these systems is included below, with additional detail related to their associated source water protection areas in subsequent sections.

2.1.1 Hidden Valley Intake

A brief synopsis of the physical characteristics of the Region's raw water intake system at Hidden Valley, as it relates to the SWPA of the study area as discussed herein, is taken directly from Stantec (2010), as follows:

> The Mannheim Water Treatment Plant system, including the Hidden Valley intake, was designed to provide a multi-barrier approach for a river based drinking water system that considers the widely varying seasonal and event-based fluctuations in water quality. Both the intake itself and the Hidden Valley water storage reservoir contribute to this multiple barrier.
>
> The first element in the intake system is the 90 m long concrete control weir with a constant sill elevation of 282.40 m across the width of the River. The physical intake at the Grand River is located on the west bank and is comprised of two rectangular 6.00 m × 1.00 m intakes set at an elevation of 280.50 m, or 1.90 m below the weir crest elevation. The intakes are gradually reduced in opening size over a length of approximately 25 m to two (2) 1.525 m × 1.00 m sluices at the pumphouse structure. The Hidden Valley Low Lift (HVLL) pumps convey the flow approximately 307 m to the 4-celled raw water storage reservoir.
>
> Perhaps the largest component of the intake protection provided at the Hidden Valley Low Lift station is the raw water storage reservoirs, in that they provide an element of detention of raw water prior to conveyance to the treatment plant at Mannheim. This detention period, theoretically as high as 48 hours but typically in the 12-24 hour range, allows for a retroactive testing and diversion of the raw water away from the drinking water system should a contaminant enter the system with a delayed notification.

In summary, as a riverine raw water supply system, the Grand River intake at Hidden Valley has inherent vulnerabilities to surface water contaminations at both acute (e.g., spills) and chronic (e.g., tong-term water quality degradation) scales. At the same time, the design and operations of the Hidden Valley intake system offer built-in protection against temporary spill conditions as opportunity exists for identified negative conditions to be flushed from the system or otherwise managed.

2.1.2 Fountain Street Well Field

A brief synopsis of the physical characteristics of the Region's wellfield supply system at Fountain Street, located east of the study area on the east side of the Grand River in the vicinity of Maple Grove Road / Fountain Street in Cambridge, is taken directly from the Grand River Source Protection Area – Approved Assessment Report (LERSPC 2022a), as follows:

> The water supply for the Fountain Street Wellfield is obtained from production well P16 and supplies water to the IUS [ed. Integrated Urban System]. A Class Environmental Assessment was completed in 2014 for the addition of a new well on Maple Grove Rd. (P18) to the Fountain Street Wellfield (MTE, 2014). Production well P16 is screened from approximately 33 m to 38 m below grade, while P18 is screened from approximately 43 to 53 m below grade. Both wells are screened within the Pre-Catfish Creek Aquifer (AFD1), which overlies bedrock. The aquifer is overlain by a thick sequence of aquitard material including the Port Stanley, Lower Maryhill and Catfish Creek Tills.

MTE (2014) also reported encountering a positive recharge boundary to the west of P18 during a 40-hour pumping test, suggesting possible recharge from the Grand River where the thickness of AFD1 was interpreted to be thicker.

2.1.3 Parkway Well Field

A brief synopsis of the physical characteristics of the Region's Parkway Wellfield supply system, located west of the study area in the Manitou Drive / Schneider Creek area of Kitchener, is taken directly from the Grand River Source Protection Area – Approved Assessment Report (LERSPC 2022a), as follows:

> The water supply for the Parkway Wellfield is obtained from production wells K31, K32, and K33. Each of these wells pumps at approximately the same rate. All production wells discharge to a common reservoir before water is pumped to the Region's IUS [ed. Integrated Urban System] system. All of the production wells are screened across depths ranging from approximately 24 m below grade to 34 m below grade within the Pre-Catfish Creek Aquifer (AFD1) which is overlain by an extensive confining to semi-confining aquitard unit consisting of the Maryhill and Catfish Creek Tills, with the Upper Waterloo Moraine Sands at ground surface.

2.2 Surface Water Hydrology and Hydrogeology

The entirety of the Hidden Valley Creek catchment area discharging to the Grand River is approximately 210 ha, with most of the contributing catchment area beyond the study area already developed to a high degree of impervious coverage. Most of the contributing headwater areas drain first to the Hidden Valley ESPA/PSW through two headwater drainage features, known as the North and West Tributaries.

The West Tributary starts at the culvert outlet discharging from the east side of Wabanaki Drive and flows east within a well-defined channel before dissipating into the open water/cattail marsh, wherein defined bed and bank characteristics cease. The West Tributary receives untreated and treated storm drainage areas north and west, and treated storm discharge from the outfall of the North Wabanaki SWM Facility, located immediately to the south.

The North Tributary originates at King St. E., immediately north of Highway 8, and bisects the Heffner Toyota site. Downstream of the Highway 8 and Hidden Valley Road crossings it also transitions from a single-thread, defined bed and bank characteristic into the wetland feature of the ESPA / PSW.

A third small tributary known as Hofstetter Creek drains northerly from the northeast portion of the study area, conveying drainage from existing natural areas across Hidden Valley Road and Highway 8 before winding its way to the Grand along the rear of residential properties fronting onto Stonegate Drive. While the catchment area for this area is contained within the intake protection zone for the Region's riverine surface water supply at Hidden Valley weir, there are no land use or drainage changes anticipated for this area and, as such, no further discussion is warranted herein.

Surface water flow monitoring completed on the West and North tributaries over approximately the last 10 years has confirmed that hydrologic characteristics are largely reflective of highly urbanized headwater drainage areas. The tributaries are largely dry or under minimal baseflow conditions during dry weather conditions, but exhibit short, peaky runoff responses following rainfall or snowmelt events in the headwater areas. As described above, flow in these defined watercourses transitions into the ESPA/PSW wetland receiver, with a large (i.e., ± 9 ha) open water area. The extent of the open water is variable, controlled to some extent by seasonal and/or event-driven fluctuations in precipitation and runoff, but primarily by beaver dam(s) that have been observed in the ESPA/PSW through aerial imagery (Kitchener, 2016-2021), drone imagery (Kitchener 2023) and field investigations (Stantec 2013, Matrix 2023). The storage effects introduced by the beaver dam and associated head pond serve to significantly dampen any precipitation event-related surface water hydrologic response through reaches of Hidden Valley Creek downstream. Monitoring did note increases in flows through reaches downstream of the beaver dam "during the early winter snow melt in January 2013 and the spring melt in early March 2013" (Stantec, 2013) which should be expected given the larger runoff volumes in such events and reduced infiltration capacity at that time of year.

The hydrogeology of the study area is complex and the subject of multiple previous and ongoing studies; the Region continues to undertake hydrogeologic assessment work in the area as such is of notable relevance to nearby surface water and groundwater supply sources. Stantec (2013/2014) includes the most up-to-date and comprehensive understanding of the local area hydrogeology, the relevant sections of which have been included in Appendix A1 of this report for ease of reference. In summary, some of the key aspects of relevance to the current study include:

- Across most of the study area there are multiple geologic units comprising the stratigraphic sequence, including both aquifer and aquitard layers.
- Given relatively coarse surficial geology across much of the study area and the upland areas above the low-lying ESPA/PSW feature specifically, it is understood that much of the incident precipitation not lost to evapotranspiration is converted to infiltration.
- That portion of upland infiltration that remains in the shallow groundwater layers by virtue of intervening aquitard layers migrates laterally and emerges as groundwater discharge supporting the ESPA/PSW.
- Within the ESPA/PSW feature and the esker forming a ridge along its southern limits, Stantec 2013/ 2014 noted the significant thinning and/or absence of aquitards and postulated the existence of a hydraulic "window" into the deeper aquifer system.
- The beaver dam(s) and associated head pond are understood to have <u>significant</u> impact on both groundwater flow / recharge and stream discharge conditions, increasing the former and moderating the latter. Stantec (2013) completed an assessment of the relative importance of the beaver dam on local groundwater recharge through the comparison of two scenarios, (1) with the dam in place and recharge occurring within the extent of the associated ponded area, and (2) beaver dam absent and recharge only occurring below the Creek corridor itself. Though the analysis should be considered relatively "high-level", it highlighted that the difference in local recharge could be close to 200,000 m^3/year (40 × more with dam in place than absent).

In short, in addition to being a significant environmentally sensitive area, the approximately 34 ha ESPA/PSW is the hydrologically / hydrogeologically dominant landscape feature in the subwatershed, with a complex and dynamic surface water / groundwater relationship that is significantly impacted by the presence and activities of beaver throughout the area. With loam and sandy loam over gravel dominating the surficial soil and high groundwater table, surface water / groundwater exchange plays a large role in the water balance of the wetland.

Downstream of the ESPA/PSW, the open water / cattail characteristic transitions back to a well-defined, single-thread channel officially known as Hidden Valley Creek that flows east / southeast across a couple private properties before its at Hidden Valley Road, and discharge to the Grand River. Flows through this reach of the system are controlled by the beaver dam and supplemented to a minor extent through groundwater discharge.

2.3 Groundwater/Surface Water Quality (Chloride)

The primary source of information reviewed as part of the current work relating to the groundwater / surface water quality characteristics on and around the study area is contained within the Stage 1 Hydrogeology Study, River Road Extension – King Street to Manitou Drive (Stantec 2013) and the subsequent update 2013 Pre-Construction Groundwater and Surface Water Monitoring, Proposed River Road Extension – King Street to Manitou Drive, Kitchener, ON (Stantec 2014). For ease of reference, a sampling of key data from these reports has been included within Appendix A2 in tabulated and graphical format and summarized below.

Data provided by the Region relating to chloride monitoring at the Parkway Well Field correlated well to the observations in Stantec (2014) and served to help characterize the primary receiving water supply system of concern to the current study.

The ubiquitous application of road salts in urban contexts and along roadways has long been identified as the primary source of elevated sodium and chloride levels in groundwater and surface water systems across southern Ontario. With reference to the appended data, it is evident that conditions within the study area and to the west, toward the Parkway Well Field, are no different. Shallow observation wells near the northeast limits of the study area, adjacent to the Highway 8 and Hidden Valley Road corridors show elevated chloride levels in the 600-1000 mg/L and 200 mg/L range, respectively. West of the study area, nearing the Parkway Well Field, observations at both shallow and deep wells noted chloride concentration in the range of 400-500 mg/L and 600-700 mg/L, respectively. These values are generally in agreement with monitored values observed at Well K2, the easternmost of the Parkway wells.

Within the undisturbed or actively farmed areas within the study area, at locations removed from the surrounding roads, chloride levels were routinely observed in the range of 6-30 mg/L, values much more aligned with what could be expected naturally in the area, or with minimal anthropogenic impacts.

Chloride concentrations observed within the surface water system are also generally unsurprising in their characteristics. At monitoring locations SW2-11 and SW3-11, coincident with upstream limits of the west and north tributaries within the study area, chloride levels are omnipresent and exhibit generally expected seasonal trend behaviour (e.g., higher in winter and spring), with limited outliers (e.g., a value of 478 mg/L observed at SW3-11 in July 2013). Further validating the hydrologic impacts of the beaver dam and associated ponding areas, and the groundwater recharging nature of the ESPA/PSW itself, it is interesting to note that chloride concentrations downstream of the beaver dam, at the Hidden Valley Creek crossing of Hidden Valley Road, are routinely lower than upstream values and far more consistent across seasonal monitoring.

The primary "outliers", in terms of locations where elevated chloride concentrations are observed in areas that might not be anticipated due to lack of developed land uses or nearby roads / parking where salt application occurs, are the two wells (K-PY-OW2-12 (A & B) and K-PY-OW7-12) located near the south and southeast limits of the ESPA/PSW, adjacent to and within the east-west esker formation. Both Stantec 2013 and 2014 identified these observations, concluding that the elevated levels are likely the result of the absence of, and glacially reworked, aquitard layers in this area, the result of which is a hydraulic "window" or direct connection between surface and groundwater systems in this area. Stantec (2014) also noted that, since concentrations observed in the deep groundwater wells here were generally higher than those observed in the surface water monitoring, "surface water infiltration within Hidden Valley is unlikely to be the source of the elevated sodium and chloride concentrations." Instead, "it is concluded that the source of the elevated sodium and chloride concentrations at these locations is likely from winter road salting in the area of Wabanaki Drive and Fairway Road."

3 Vulnerable Area Characterization

There are three types of vulnerable areas covered by the GRSPP, all of which are present within the study area, namely:

- Intake protection zones (IPZs) – An IPZ is the area around a surface body of water where water is drawn in and conveyed for municipal drinking water.

Wellhead protection areas (WHPAs) – WHPAs are areas of land around a municipal well where land uses / activities have the greatest potential to affect the quality of water flowing into the well. [1]

- Issue Contributing Areas (ICAs) – An ICA is an area within a vulnerable area where activities could contribute to water quality issues.

At project outset, there were vulnerable areas defined as extending within the study area associated with two different drinking water sources; an IPZ-2 associated with the Region's Hidden Valley Surface Water Intake located on the Grand River immediately east of the study area, and a WHPA-D associated with the Fountain Street Well Field that includes the Region's Supply Wells P16 and P18. A third drinking water source, the Parkway Well Field comprised of Supply Wells K31, K32, and K33 located 1.0-1.2 km to the west, had WHPAs that extended close to, but not within, the study area. The vulnerable area delineations for all three of these sources are illustrated on Figures 2 and 3, respectively. The characterizations of these existing vulnerable areas are described in more detail in the following sub-sections.

3.1.1 Hidden Valley Surface Water Intake at the Grand River – IPZ-2

The IPZ-2 for Region's raw surface water intake at the Hidden Valley weir was originally defined in 2010 (Stantec 2010), in accordance with the Technical Rules: Assessment Report – Clean Water Act, 2006, Proposed Amendments – August 24, 2009 (Technical Rules; Ontario Ministry

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[1] A note on terminology used herein. It is acknowledged that Wellhead Protection Areas (WHPAs), as defined and delineated within Source Water Protection Assessment Reports (ARs), and Wellhead Protection Sensitive Areas (WPSAs), as defined / delineated in the Region's Official Plan (OP), are not necessarily equivalent. Similarly, the establishment of "land use" policies and threat-based "activities" policies within the OP and AR, respectively, are not necessarily synonymous.

For the purposes of the current work, and for simplicity, the WHPAs are considered both more conservative and up-to-date vulnerability zones, as compared to the WPSAs and, therefore, are used define the "areas of concern". Similarly, the application of road salt "activity" is considered more-or-less ubiquitous with any proposed developed "land use", and so these two terms are also used interchangeably.

of the Environment 2009). The extent of the IPZ-2, as it relates to the current study area, is illustrated on Figure 2.

The IPZ-2 represents the locally contributing drainage area of the upstream watercourses systems and adjacent lands from which the water intake plant operators may have little or no time to react to a potential contaminant discharge. In the case of the Hidden Valley Intake, and in recognition that the Region's operators require very little time to respond to notification of a spill and shut down the intake's pumps, the IPZ-2 for this system was set to the minimum permissible by the Technical Rules, or 2 hours.

Most of the contributing riverine and creek system upstream of the intake convey flows with reasonably predictable velocities and, as such, the distance that a potential spill or other deleterious effect could travel in 2 hours could be estimated with some certainty. In the case of the Hidden Valley Creek subwatershed, however, the complex hydrodynamics of the ESPA/PSW feature introduce substantial uncertainty into the protection zone's delineation. The travel time to the intake from a point in Hidden Valley Creek itself, downstream of the ESPA/PSW, would almost certainly be less than 2 hours, meaning that the zone had to be extended upstream to a point somewhere *inside* the ESPA/PSW feature from which the additional time-of-travel to the 2-hour limit could be realized. Attempting to better understand travel time through the ESPA/PSW feature, Stantec completed dye tracer testing within the feature, but were unsuccessful in quantifying time-of-travel characteristics – i.e., despite injecting dye at the inlet tributary and monitoring downstream for 3 days, no evidence of the injection was observed at the outlet. With no certainty as to which point within the ESPA/PSW would be appropriate, the decision was made to conservatively delineate the IPZ-2 at the limits of the feature, an approach that was anticipated to have little consequence to land use planning as development would not occur within the boundaries of the feature in any event.

However, when bounding the extent of the IPZ-2 around "a surface water body that may contribute water to the intake" in the prescribed minimum travel time, the Technical Rules also require that "if a Conservation Authority Regulation Limit is in effect in the IPZ-2, the area of land that is within the Conservation Authority Regulation Limit" must also be included in the zone's delineation. Given this, the IPZ-2 was extended onto the landscape beyond the ESPA/PSW itself, to the GRCA's Regulation Limit.

An element of the current assessment work is to confirm if the boundaries of the IPZ-2 require revision to reflect any changes that may have occurred or new knowledge about the feature. Under existing conditions (i.e., pre-Hidden Valley Secondary Plan implementation), and despite repeated attempts at hydrologic modeling / calibration, there have been no substantive changes or new knowledge gained related to the hydrodynamic characteristics of the ESPA/PSW and, as such, it is suggested that the logic of the original IPZ-2 delineation remains. Short of gaining an understanding of where, within the ESPA/PSW feature the actual 2-hour time-of-travel line should be drawn, the most reasonable approach, though conservative, is to continue to bound the entirety of the feature. Further, as the Technical Rules have also not changed in this regard, the extension of the IPZ-2 around the feature to the GRCA's Regulation Limit should also remain.

However, as the GRCA's Regulation Limit has been refined in the interim period since initial 2010 delineation, there *is* a need and likely a benefit, from a land use perspective, to updating the IPZ-2 to align with this new delineation in the area surrounding the ESPA/PSW and Hidden Valley Creek corridor. With reference to the yellow, dashed line included on Figure 2, the update Regulation Limits have generally shifted toward the ESPA/PSW updated Regulation Limit, disencumbering portions of the proposed development areas from source water protection considerations. Though subject to administrative review and approval processes, these revisions could be implemented at anytime.

Further, since the GRCA's Regulation Limit also reflects Regulatory features only peripherally-related to drainage – e.g., ecology, slopes (erosion / valley) – and these are often defined using default, conservative assumptions and/or automated processes (i.e., default setbacks), they are almost always subject to revision upon further study. It should be expected that the more detailed, site-specific studies to be completed as part of development planning will almost certainly result in further revisions to the Regulation Limit, likely shifting in the direction of environmental features and away from potential development areas. With an expectation that these site-specific updates and associated Regulation Limit revisions will be forthcoming in relatively short timeframe, and with the knowledge that the current delineation likely doesn't present a significant constraint to current planning (see Section 4.1), it is recommended that updates to the IPZ-2 delineation within the study area could likely be deferred and completed as part of a more holistic update with no consequence to the Hidden Valley Secondary Planning processes.

The entirety of the IPZ-2, including that which covers portions the study area, has a single assigned vulnerability score of 7.2. The potential impacts of the existence of the IPZ-2 as it relates to the Hidden Valley Secondary Plan are discussed in Section 4.1.

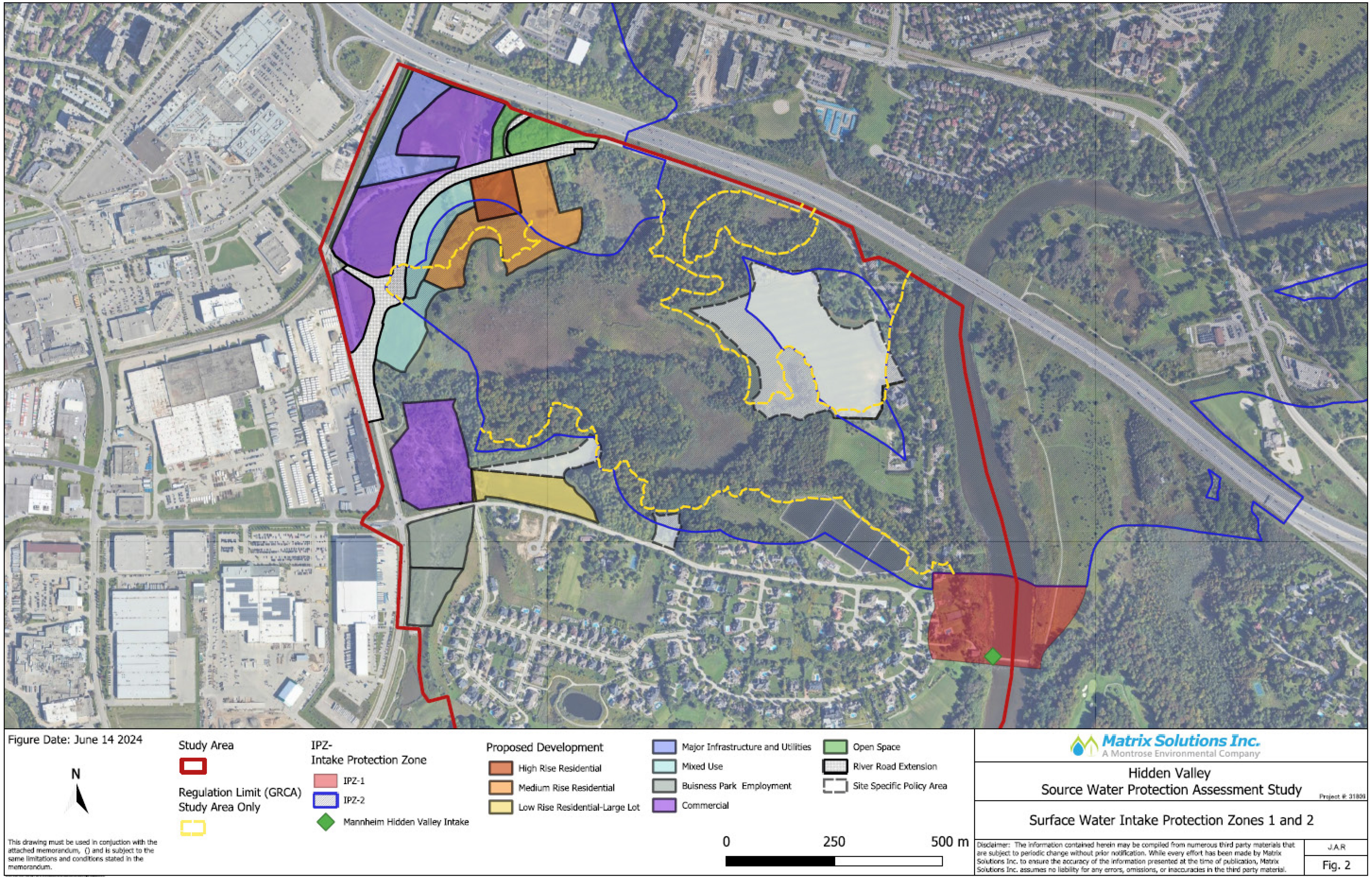

Figure 2 Hidden Valley Surface Water Intake – Intake Protection Zones 1 and 2

3.1.2 Fountain Street Wellfield – WHPA-D

The Fountain Street Wellfield, which is comprised of municipal supply wells P16 and P18, is located east of the study area on the east side of the Grand River in the vicinity of Maple Grove Road / Fountain Street, in Cambridge. The only WHPA associated with this supply system that extends within the study area limits is WHPA-D, which defines the surface and subsurface areas within which the time-of-travel to the wells is less than or equal to 25 years but greater than five years. The extent of the currently approved WHPA-D that overlaps the current study area is illustrated on Figure 3. The protection area has been assigned a vulnerability score of 2 and there are no drinking water threats identified within the zone nor identified issues.

In a separate study being undertaken by the Region of Waterloo concurrently to the Hidden Valley technical studies, including this assessment, it is understood that the WHPAs for at least some of the municipal supply systems, including the Fountain Street Wellfield, are currently being remodelled / reassessed and that there is a reasonable expectation that some will see at least a slight change in their delineations.

Indeed, as the current study was nearing completion the Region was able to provide **draft, unreviewed, and unapproved** shapefiles of redefined WHPAs for the Fountain Street Wellfield, which have been included on Figure 3 as dashed lines of similar colour to the existing, approved WHPAs. While the updated delineation indicates that, if such is ultimately determined to replace the existing delineation, the WHPA-D will extend slightly further onto the study area but there is no indication at present, nor is there any reason to believe, that the relative vulnerability of the protection area will change, or that new threats or issues will be identified.

Though remaining in draft, unapproved status, the potential impacts of the more conservative redefined Fountain Street Wellfield WHPA-D, as it relates to the Hidden Valley Secondary Plan, are discussed in Section 4.2.

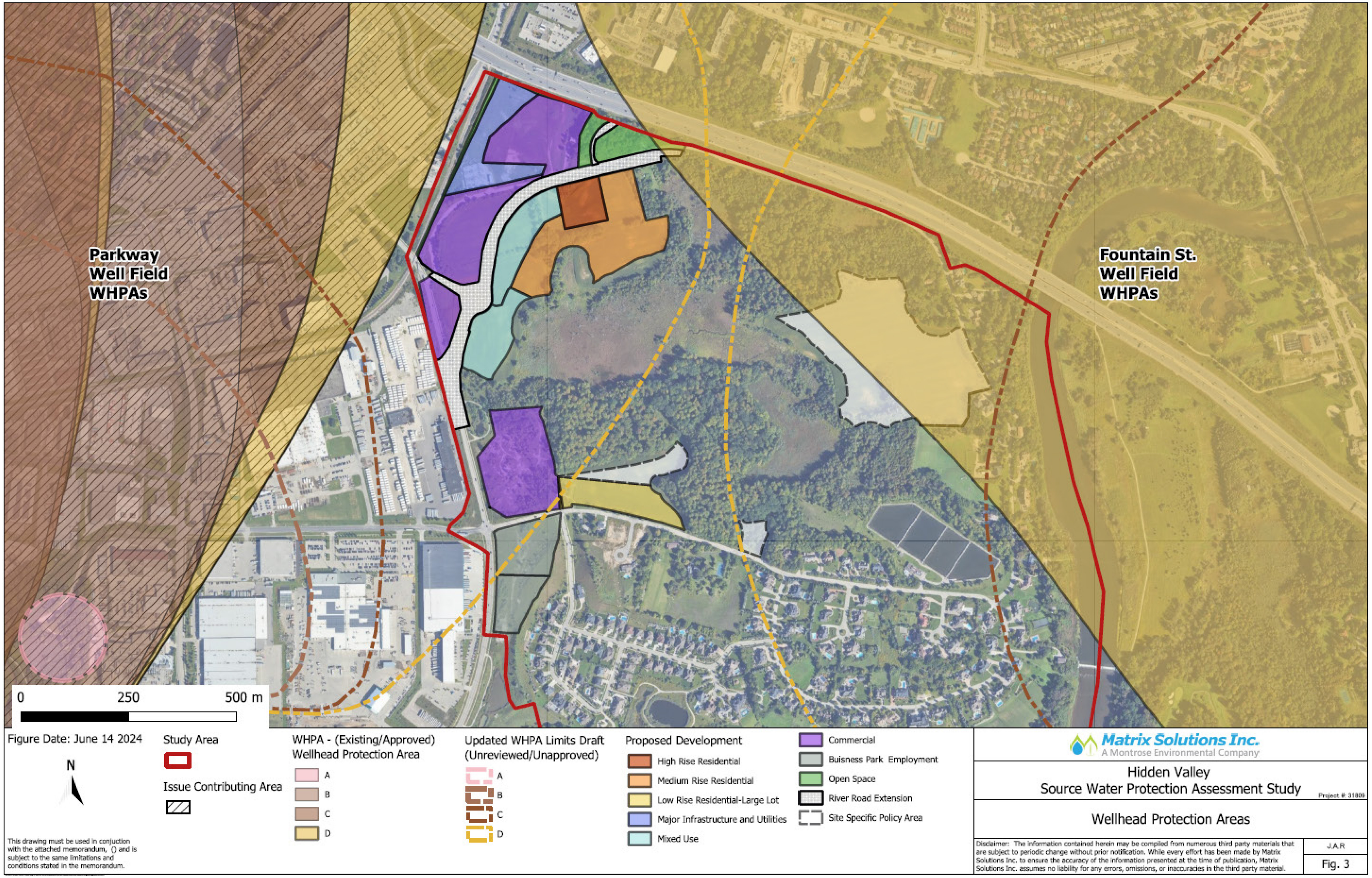

Figure 3 Fountain St Wellfield (east) and Parkway Wellfield (west) – Wellhead Protection Areas

3.1.3 Parkway Wellfield – WHPA-D/ICA

The Parkway Wellfield, which is comprised of municipal supply wells K31, K32, and K33, is located west of the study area in the Manitou Drive / Schneider Creek area of Kitchener.

The most extensive of wellhead protection area delineations, the WHPA-D, defines the surface and subsurface areas within which the time-of-travel to the wells is less than or equal to 25 years but greater than 5 years. The extent of the currently approved Parkway Wellfield's WHPA-D, as illustrated in the shaded WHPAs on Figures 3 and 4, extends easterly toward the study area, but stops just west of Fairway Road, just beyond the study area limits.

The WHPA-D has been assigned a vulnerability score of 2 and there are no drinking water threats or "significant conditions" identified within this zone.

Unlike the Fountain Street Wellfields described above, the Parkway Wellfield does have associated, designated Issues identified including sodium and chloride, in all three wells, and trichloroethylene (TCE), in the easternmost well (K32). The following text and graphics, referenced directly from the Grand River Source Protection Area – Approved Assessment Report (LERSPC 2022a), summarizes the Issues:

> ***<u>TCE</u>***
>
> Low concentrations of trichloroethylene are consistently detected at well K32 (the easternmost well). Recent concentrations (since 2013) have been between 2 and 5 µg/L compared to the ODWS of 5 µg/L and the MOE guidance value of 2.5 µg/L. In addition, there were two instances where samples where concentrations were higher than the MOE guidance value. Trichloroethylene is generally not detected (< 0.5 µg/L) at wells K31 and K33. Recent fluctuations in TCE concentrations at K32 may indicate an increasing trend (Figure 8-11) [ed: Figure 5, herein].
>
> Therefore, TCE has been designated as an Issue for well K32.
>
> As a detailed assessment of properties that might have used TCE has not been completed, the source of the TCE to well K32 is unknown.

Chloride and Sodium

> The Parkway production wells have exhibited increasing chloride concentrations since at least 1992 when Region monitoring began. Recent chloride concentrations in raw water have risen to between 275 and 750 mg/L, compared to the [ed: Ontario Drinking Water – Aesthetic Objective] ODW-AO of 250 mg/L (Figure 8-12) [ed: Figure 6, herein]. Sodium concentrations are currently elevated (approximately 125 to 365 mg/L) with an increasing trend, compared to the ODW-AO of 200 mg/L for sodium (Figure 8-13) [ed: Figure 7, herein].
>
> Based on the elevated concentrations at the supply wells and the increasing concentration trends, both Sodium and Chloride are designated Issues for the Parkway wells.
>
> The primary source of chloride and sodium to the wellfield groundwater is consistent with historical application of de-icing salt to roads and parking lots (WESA, 2013). The Issue Contributing Area is delineated as the 25 year time-of-travel for the Parkway Supply Wells and shown in Map 8-80. [ed: ref. Figures 3 and 4, herein]

Given that the existing, approved WHPA-D boundaries do not extend onto the study area, the designation of the zone as an Issue Contributing Area was initially expected to have no significance to the current study. However, in a separate, concurrent study being undertaken by the Region of Waterloo, it is understood that the WHPAs for at least some of the municipal supply systems, including the Parkway Wellfield, are currently being remodelled / reassessed and that there is a reasonable expectation that some will experience at least slight changes in their delineations.

Indeed, as the current study was nearing completion the Region was able to provide **draft, unreviewed, and unapproved** shapefiles of redefined WHPAs for the Parkway Wellfield, which have been included on Figures 4 and 5 as dashed lines of similar colour to the existing, approved WHPAs. The updated delineation indicates that, if such is ultimately determined to replace the existing delineation, the WHPA-D will now extend within the study and encompass most of the potential development areas at the north portion of the Secondary Plan area but there is no indication at present, nor is there any reason to believe, that the relative vulnerability of the protection area will change.

Though remaining in draft, unapproved status, the potential impacts of the more conservative, redefined Parkway Wellfield WHPA-D, as it relates to the Hidden Valley Secondary Plan, are discussed in Section 4.3.

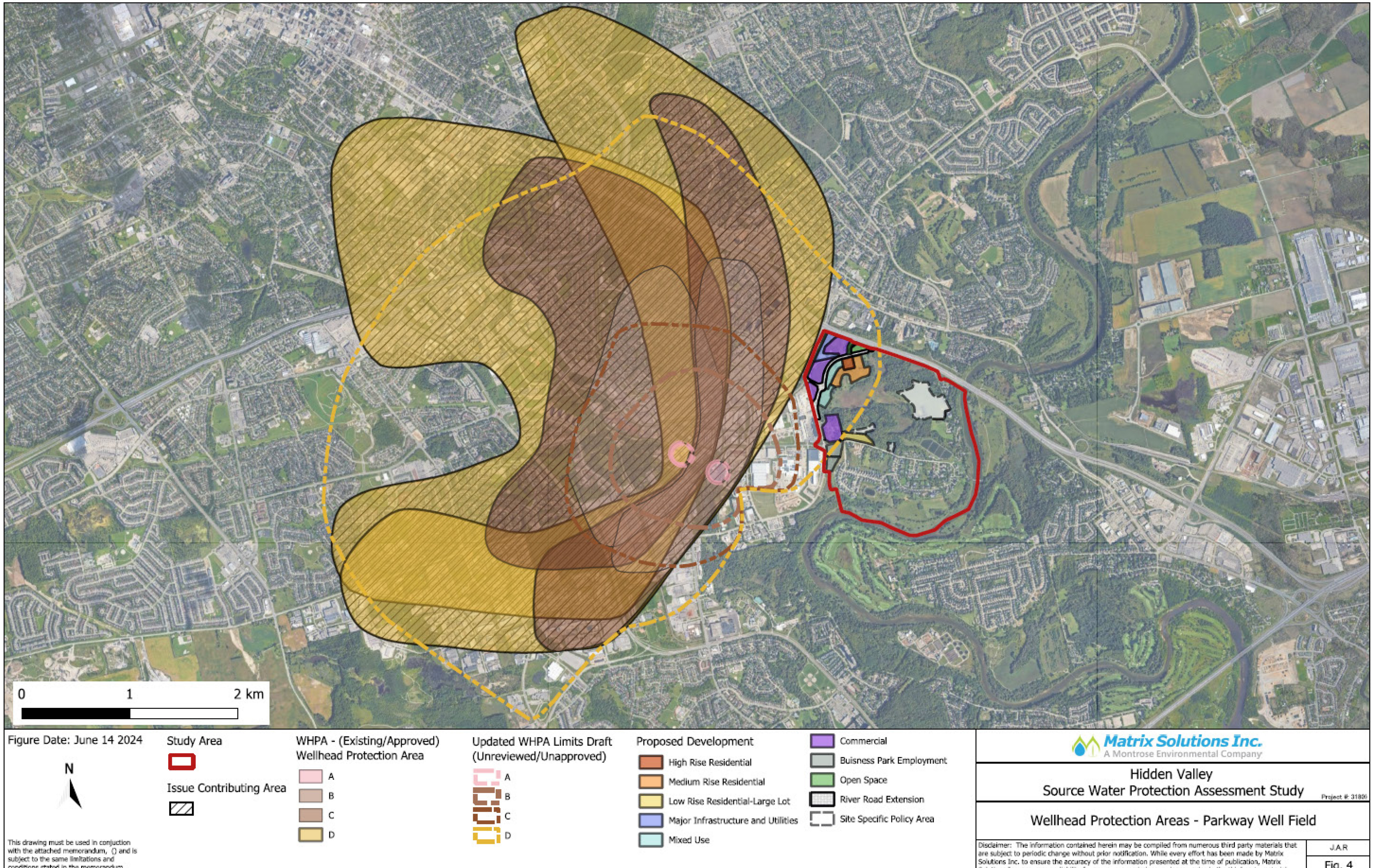

Figure 4 Wellhead Protection Areas - Parkway Well Field

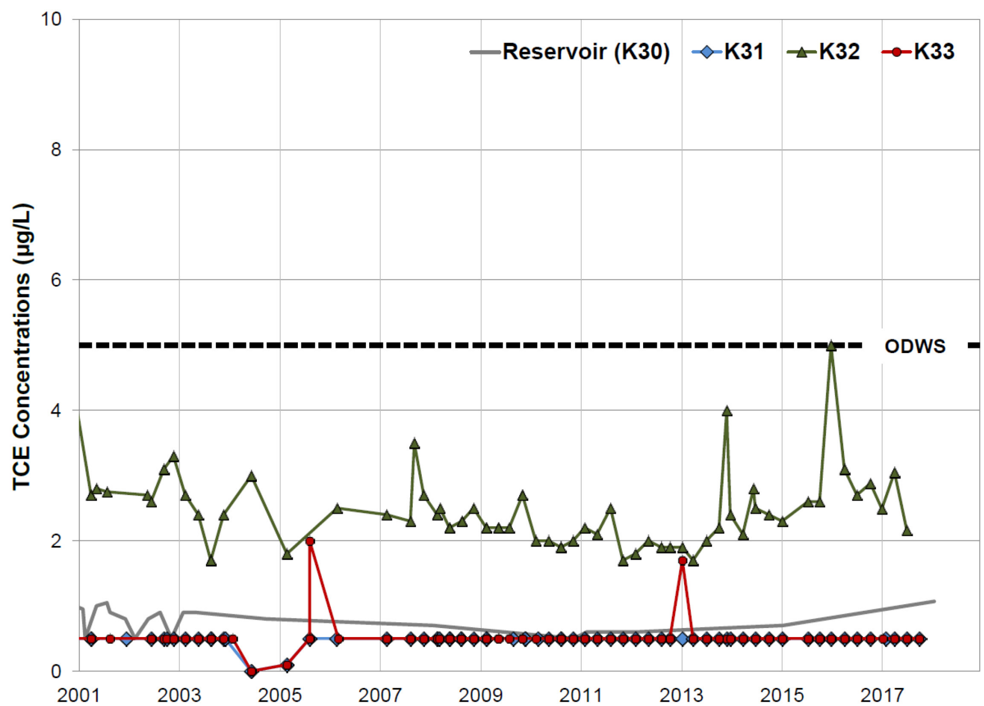

Figure 5 Trichlorethylene Trends in the Raw Water at the Parkway Supply Wells and Common Reservoir, Kitchener
(reproduced from Figure 8-11, LERSPC 2022a)

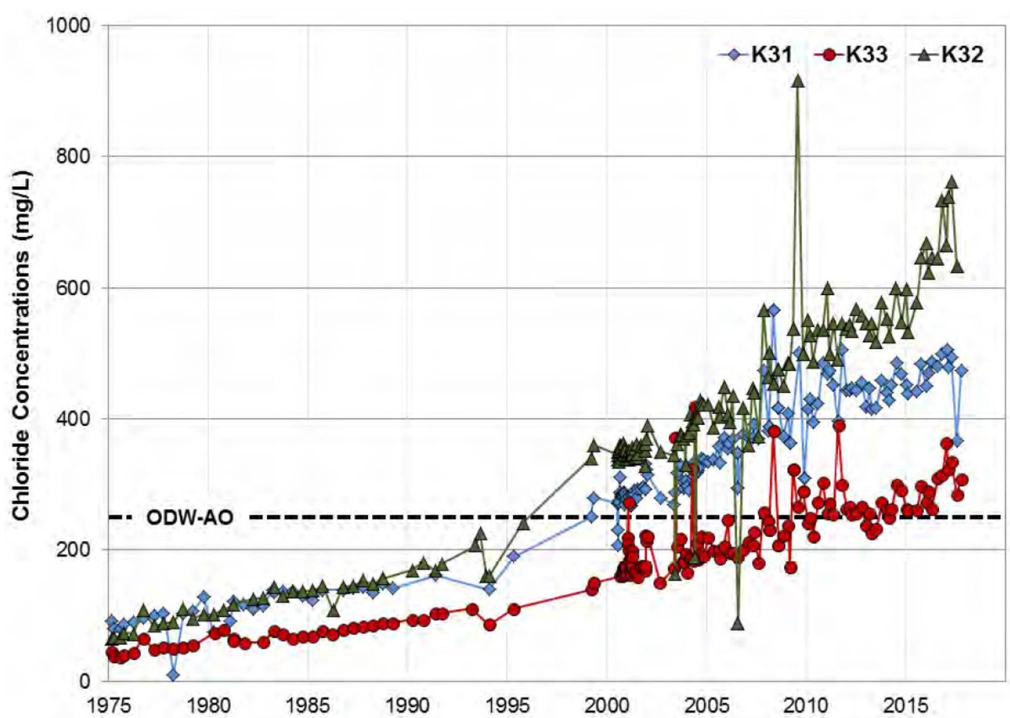

Figure 6 Chloride Trends in the Raw Water at the Parkway Supply Wells, Kitchener
(reproduced from Figure 8-12, LERSPC 2022a)

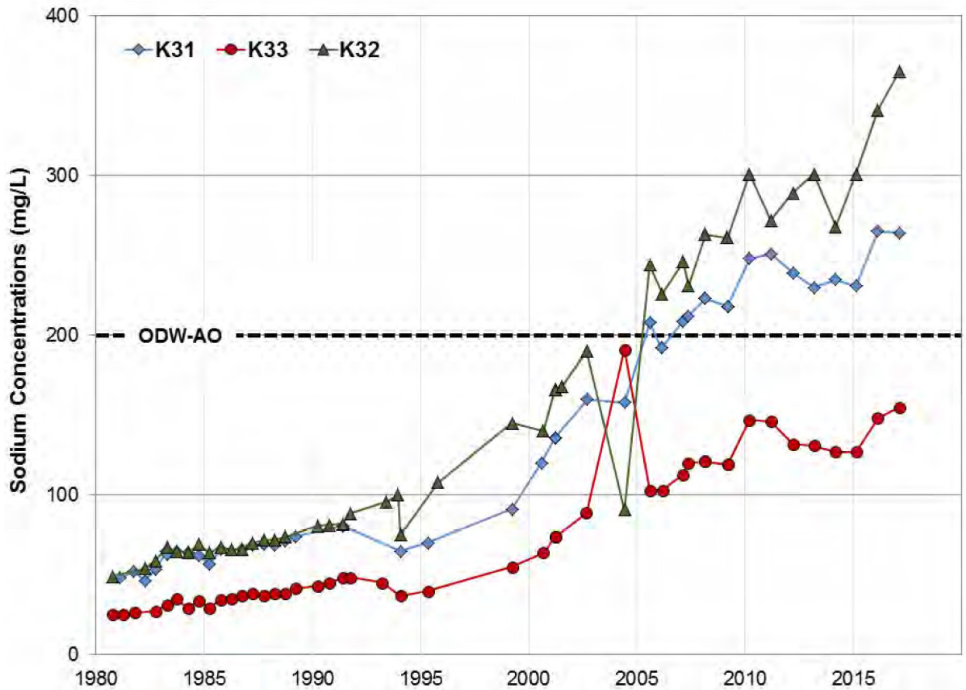

Figure 7 Sodium Trends in the Raw Water at the Parkway Supply Wells, Kitchener
(reproduced from Figure 8-13, LERSPC 2022a)

4 Proposed Conditions Source Water Impact Assessment

As discussed in Section 3 and illustrated on Figures 2-4, much of the proposed development area lies within existing or draft, unapproved source water protection zones associated with one or more of the three municipal drinking water supply systems local to the study area. The most important approach to protecting the quality and quantity aspects of these drinking water systems is through the implementation of land use planning decisions and processes in accordance with Provincial policy and the Provincial Policy Statement, and to limit potential development-related changes that could result in adverse effects.

It is recognized that not all land uses represent the same level of risk to drinking water supplies. Through the Official Plan, the Region has identified and categorized a range of land uses of primary concern that are to be prohibited entirely or, depending on the vulnerability of the protection zone and the inherent risk represented, permitted subject to further study and mitigation planning. The Region's listing of inherently moderate, high, or very high risk activities, and those that might otherwise serve to increase the inherent vulnerability of a source, is contained in Schedule 'B' of the Official Plan, a copy of which is included in Appendix A3 of this document for ease of reference.

As illustrated on the Council-approved Hidden Valley Land Use Master Plan (Figure 1), planned development within the study area is anticipated to include a range of land uses, including:

- Transportation corridors – local, arterial, and access ramps to King's Highway #8
- Light-rail transit corridor
- Commercial
- Range of residential, including low-rise, medium-rise and high-rise
- Mixed-use (commercial / residential)
- Business Park Employment
- Major infrastructure and utilities
- Natural Heritage Conservation / Open Space

The connection between proposed land uses and those of most concern to aspects of source water protection, and the potential need for consideration in the current planning context are described in the following sections.

4.1 Hidden Valley Surface Water Intake IPZ-2/Development Considerations

As described in Section 3.1.1, the IPZ-2 delineation for the Hidden Valley Surface Water Intake extends well within the study area under existing conditions and, even with the recommended incorporation of revisions to align the limits with updated and/or anticipated GRCA Regulated Limits, will continue to do so. The assigned vulnerability score for the IPZ-2 is 7.2 is lower than the trigger for application of associated Source Protection Plan policies (e.g., those pertaining to activities such as hauling, treatment, or land application of sewage, landfilling municipal waste, storage of hazardous, stormwater management, storage / handling of liquid fuels, etc.).

Most of the IPZ-2 area within the study area overlaps the Hidden Valley Creek natural corridor, ESPA/PSW limits, and associated buffers and will not be subject to any land use changes associated with the Hidden Valley Secondary Plan. However, as shown on Figure 2, there may be some areas remaining within the IPZ-2 even following the re-delineations recommended to reflect the existing or future, anticipated updated to the GRCA's Regulation Limits, most notably along the northern edge of the ESPA/PSW where the Council-approved Master Plan identifies "Mixed-Use" or "Medium-Rise Residential" land uses.

As it relates to potential development within the IPZ-2, Regional Official Plan Policy 8.A.22 states:

> Within Surface Water Intake Protection Zone 2, development applications will comply with the following:
>
> (a) Category ‘A’ uses will not be permitted; and
>
> (b) Category ‘B’, ‘C’ and ‘D’ uses and stormwater management ponds (or other ponds) may be permitted subject to further study in accordance with Policy 8.A.4.

Within the Hidden Valley Master Plan, there are no Category ‘A’ land uses and only limited potential for Category ‘B’, ‘C’, or ‘D’ uses explicitly proposed within the study area, and these could be prohibited through City planning policies (ref. Section 5.1 of this report). The proposed SWM Strategy, prepared to inform Hidden Valley Secondary Plan review, indicates that end-of-pipe stormwater management facilities will likely be implemented along the southerly limits of the developing areas immediately north of the ESPA/PSW and potentially within remnant GRCA Regulation Limits. However, given the types of generally low-risk land uses that will drain to these facilities and their inherent treatment and detention benefits that serve to further increase the time-of-travel for any spills within the catchment area, it is expected that further study and/or justification needs to satisfy Regional source water protection requirements will be minimal.

4.2 Fountain Street Wellfield WHPA-D/Development Considerations

As described in Section 3.1.2 and illustrated on Figure 3, the only WHPA associated with to the Fountain Street Wellfield that extends onto the study area, under either existing or draft, unapproved delineations, is the WHPA-D. The protection area has been assigned a vulnerability score of 2 and there are no drinking water threats identified within the zone nor identified issues.

The only potential land use change associated with the implementation of the Hidden Valley Master Plan involves the “Site-Specific Policy Area” on the east side of the ESPA/PSW. Through consultation with the City, and as considered within the SWM Strategy component of the ongoing technical studies, it is understood that, should this area be approved for development, it will likely take the form of either low-rise or low/medium-rise residential, complete with an end-of-pipe stormwater management facility discharging westerly into the natural area. In short, this is a low-risk land use anticipated within a low vulnerability source water protection zone and, therefore, it is expected that further study and/or justification needs to satisfy source water protection requirements will be minimal.

4.3 Parkway Wellfield WHPA-D and ICA/Development Considerations

As described in Section 3.1.3 and illustrated on Figure 3 and 4 the existing, approved WHPAs associated with the Parkway Wellfield do not extend westward within the study area limits. However, the draft, unreviewed/unapproved limits do shift the limits eastward, into the study area to an extent that most of the potential development lands along the north and west limits, as well as most of the new River Road extension corridor, would be captured within this updated protection zone. Though remaining in draft, unapproved status, the current study has adopted the conservative approach of assuming the ultimate Parkway WHPAs *will* extend eastward and that a SWPA is warranted. Should this assumption ultimately prove false, the subsequent assessment and planning approach can be modified and/or dismissed.

The land uses proposed within the Hidden Valley Master Plan areas that will be captured within the new Parkway WHPA-D include all of those listed in Section 4.0, above, save for low-rise residential. Despite the variety of land uses identified through this portion of the Master Plan, there are no Category ‘A’ uses proposed and only limited potential for Category ‘B’, ‘C’, or ‘D’ uses explicitly identified within the study area, and these could be prohibited through City planning policies (ref. Section 5.1 of this report).

While the Parkway WHPA-D has a low vulnerability designation and/or lack of identified threats that might have led to a “limited significant source water protection concern” conclusion, as was the case for the IPZ-2 and the Fountain Street WHPAs, the designation of the Parkway Wellfield capture areas as an Issue Contributing Area (ICA) does mandate further assessment. With trichlorethylene (TCE), sodium, and chloride identified as Issues, an assessment of any potential activities that might accompany the proposed Secondary Plan development deemed to be a potential source of the contaminants is required.

Of the three chemicals of concern, TCE can be effectively dismissed from further evaluation herein as none of the typical activities that might generate the contaminant have existed within study area in the past, nor are they expected as part of the Master Plan development. A list of such activities, reproduced from Table 8-9 of LERSPC, 2022a, includes:

- Sewage Systems or Sewage Works – Combined Sewer discharge from a storm outlet to surface water

- Sewage Systems or Sewage Works – Industrial Effluent Discharges
- Sewage Systems or Sewage Works – Sewage treatment plan bypass discharge to surface water
- Sewage Systems or Sewage Works – Storage of sewage (e.g., treatment plant tanks)
- Handling and storage of a DNAPL (Dense Non-Aqueous Phase Liquid)
- Waste Disposal Site – Landfilling (Municipal Waste)
- Waste Disposal Site – Landfilling (Solid Non Hazardous Industrial of Commercial)
- Waste Disposal Site – Liquid Industrial Waste Injection into a well

On the other hand, the anticipated application of de-icing salts on public roads and typical areas within private development sites (e.g., vehicular and pedestrian access routes and parking areas) within the WHPA-D/ICA, especially when combined with the high infiltration characteristics of both the potential development areas and the lower-lying ESPA/PSW feature, does require further assessment throughout the development design, review, and approval processes. Section 8.B of the Region's Official Plan establishes the requirements for such studies, with guidance for their completion provided in the Source Water Protection Guidance Document: Salt Impact Assessment (ROW, 2016). The City's Official Plan policies (Section 7.C.1) supports the Region's requirements.

The following subsections document the methodology and results of the Salt Impact Assessment completed as part of this study.

4.4 Salt Impact Assessment/Chloride Mass Balance Analysis

To assess the impact of de-icing salt application on groundwater supply systems, most notably the Parkway Supply Wells, the total mass of chloride potentially contributing to groundwater recharge originating from salt application activities within the WHPA-D capture zone of the study area can be estimated under post-development conditions and compared with known values observed at the well field.

To estimate the total chloride mass loading from the study area, local roads and private parking areas associated with the following land uses (Figure 3) have been included:

- Commercial
- High-rise residential
- Low-rise residential – estate
- Low-rise to medium-rise residential
- Medium-rise residential

- Mixed-use
- Business Park employment
- Local Road – municipal

For the purposes of the current analysis, which is concerned with the potential impact associated with the development of the Hidden Valley Master Plan concept and serves as technical input to the Secondary Planning activities, the definition of the "study area" and the consideration of land use changes <u>does not</u> specifically include the extension of River Road and the on-ramp to Highway 8. While acknowledging that both the new road and the development of surrounding lands will have impact on aspects of local hydrology, hydrogeology, and source water protection, the River Road extension and on-ramp are being completed by the Region essentially independently of the Hidden Valley Master Plan / Secondary Plan processes.
A similar source water protection / chloride mass loading analysis was completed for the River Road extension project through the Stantec 2013/2014 work, though such may benefit from an update if/when the currently draft unreviewed/unapproved wellhead protection areas delineations are adopted as a greater portion of that project will be captured within the wellhead protection zone.

As it relates to lands developing as part of the Hidden Valley Master Plan / Secondary Plan, the mass balance approach adopted herein incorporates the following assumptions:

- For medium-rise residential properties, 80% of the plan area is assumed impervious, whereas for high-rise residential, mixed-use, commercial, and business park employment, the value rises to 90%.

- Half of impervious coverage on any type of development has been assumed to be roofs, from which all runoff is considered "clean" and salt-free. In accordance with the stormwater management strategy for the developing areas, as documented under separate cover, runoff from the first 25 mm of every precipitation event is to be directed to at-source infiltration measures. Per Appendix C of MOE 1994(A), capture of the first 25 mm of runoff is roughly equivalent to 95% of annual precipitation.

- Half of the impervious coverage on any type of development is assumed to be at ground level and subject to salt application (e.g., vehicular access, parking, walkways). All runoff from these areas is to be directed to end-of-pipe stormwater management (SWM) facilities for water quality and quantity control prior to discharging to the surface receiving systems (defined tributaries or open water areas of ESPA/PSW).

- 10% of the salt applied on ground surface impervious areas is assumed to infiltrate “at-source” through the remaining pervious areas on all types of development. Though no salt is directly applied to these areas, it is assumed that such is transferred to them through snow plowing / shovelling and/or splash from adjacent vehicular travel lanes.

- Of the 90% of salt applied that is assumed to remain in the runoff directed to SWM facilities and the ESPA/PSW, 10% is assumed o remain in the surface water system for discharge to Hidden Valley Creek and the Grand River, while 80% is assumed to be infiltrated within the ESPA/PSW.

- As the WHPA-D roughly bisects the ponded area of the ESPA/PSW, it is assumed that half of the salt is infiltrated within the capture zone to the Parkway Well Field with the other half transmitted to shallow groundwater systems for discharge to downstream surface water receivers (e.g., Hidden Valley Creek) or deeper recharge away from the Parkway capture zones.

- The net result of the above is that half of all salts and associated chlorides applied to private development sites is assumed to ultimately be captured within the Parkway supply system. This is considered conservative by some measures (e.g., Region (2016) guidance suggests only 28% of salt applied to roadways is conveyed to groundwater systems) but does try to account for the somewhat unique aquifer recharge characteristics found in Hidden Valley ESPA/PSW.

Road Lengths, Parking Areas, Salt Application Rates and Infiltration

Figure 3 illustrates that portion of the study area captured within the draft, unreviewed / unapproved WHPA-Ds of the Parkway and Fountain Street supply sources, and the currently anticipated development approach. The development characteristics of concern to the current analysis includes:

- 0.11 km of two-lane secondary roads in the Parkway WHPA-D area, forming the anticipated emergency access connection between River Road and Fairway Road

- 8.97 ha of vehicular access lands, parking lot, and walkway surfaces in the Parkway WHPA-D area

Salt Application Rates

The annual salt application rates used for this analysis, based on Region guidance (2016), include:

- Local roads – 2.2 tonne/2-lane km
- Private sites (parking areas, vehicular access lanes, walkways) – 18.5 tonnes/ha
- (50 g/m^2 per salting event, with 37 events/year)

Mass Balance Analysis

Using the above-noted values, a mass balance analysis indicates that a total of the impact of winter salt application on the proposed Hidden Valley development lands and roads within the Parkway Well Field draft WHPA-D area was completed. A total of 166.2 tonnes/year of salt has been estimated to be applied, with half (83.1 tonnes/year) estimated to infiltrate into the subsurface. As chloride represents approximately 61% of the molecular weight of a salt molecule, this equates to approximately 50 tonnes of chloride per year added to the capture zone of the Parkway Well Field.

Impact on Groundwater Recharge to the Parkway Well Field

As outlined in Section 3.1.2 and illustrated on Figure 6, the Parkway Well Field has been experiencing increasing chloride concentrations since monitoring began in the mid-1970s. Accordingly, barring a reduction in total pumped volumes at this supply source, the mass of chloride drawn from this location is expected to increase. Using pumping rate and chloride concentration data provided by the Region for use within the current work, it is estimated that the mass of chloride withdrawn from the Parkway system was 1,260 tonnes and 1,360 tonnes in 2022 and 2023, respectively. As a result of the elevated chloride concentrations, these values are some 20% greater than those from the early 2000s, despite pumping rates having declined by roughly a third.

A comparison loading/infiltration rates to total annual withdrawn rates, it can be conservatively estimated that the potential increase in chlorides anticipated at the Parkway Well Field resulting from the development of the Hidden Valley Master Plan / Secondary Plan area is approximately 4%. Despite the range of assumptions incorporated, some confidence in this value can be gained considering that the 50 ha total area of the developing area and ESPA/PSW within the WHPA-D represents roughly 3% of the total draft, unreviewed/unapproved WHPA-D for the well field (1870 ha), most of which is fully developed as well.

5 Recommendations for Impact Mitigation/Secondary Planning

As outlined in Section 4.3, much of the Hidden Valley Plan Secondary Plan area anticipated for potential land development is located within the Issue Contributing Area for the Parkway Wellfield. With trichlorethylene (TCE), sodium, and chloride identified as Issues, any potential activities deemed to be a potential source of the contaminants warrants detailed consideration and an enhanced level of care and consideration within planning and design stages. While TCE is considered a non-concern given a lack of anticipated source activities, the application of road salts on public and private lands is generally ubiquitous, triggering the applicability of many Source Protection Plan policies.

The chloride loading and mass balance analyses described in Section 4 confirm that the development of the Hidden Valley Secondary Plan area, in general accordance with the Council-approved Master Plan concept, should not represent a significant impact on the Region's nearby water supply sources. Nevertheless, it is required practice across the Region, especially in WHPAs and even more so in those designated as ICAs for the associated contaminants, that management activities are undertaken on all sites to reduce impacts of de-icing salts as part of a holistic strategy of shared responsibility by public and private sectors alike. While each individual development application will be expected to develop and implement a salt management strategy, the following section has been prepared to provide some broader recommendations for municipal consideration. This is not intended as an exhaustive summary; designers and implementers are encouraged to adopt any and all innovations that could reasonably be shown to further mitigate associated impacts.

The Region provides many resources to all interested stakeholder related to de-icing practices and salt management. At the time of writing, a good launching point for practitioners or interested stakeholders can be found here: https://www.regionofwaterloo.ca/en/living-here/salt-management.aspx. Another key informational resource offering excellent guidance to winter maintenance contractors, and the municipalities that establish and oversee the implementation of best practices is the Smart About Salt Council (SASC), https://smartaboutsalt.com/. The SASC is a "*not-for-profit organization which offers training to improve winter salting practices on facilities and recognizes industry leaders through certification.*"

The recommendations for consideration in Secondary Planning described herein have been grouped into three primary categories for convenience, generally across the planning, design, and operational phases of a comprehensive approach to salt management.

5.1 Planning – Policy and Procedures

As outlined in LERSPC, 2022b (ref Sections 10.2 and 10.3), the Region of Waterloo has many established Source Protection Plan Policies already in place and these should be referred to and form the basis for any related City policies included within the Hidden Valley Secondary Plan.

While a number of ROW-SPP policies apply to the subject lands, one of the more notable, as it relates to the proposed development, is RW-CW-35 which provides direction on when and where Risk Management Plans will be required and, to some extent, what aspects they should entail. Specifically, the intent of Policy RW-CW-35 is:

> To ensure the existing and/or future application of road salt does not become or ceases to be a significant drinking water threat where this activity is or would be a significant threat, this activity shall be designated for the purpose of Section 58 of the Clean Water Act, 2006 and a Risk Management Plan shall be required within the following areas and for the following activities:
>
> a. Existing:
>
> i. Application of Salt on Roadways;
>   - i. In Wellhead Protection Areas A and B where the vulnerability is equal to ten (10);
>   - ii. Where a Chloride and/or Sodium Issue has been identified, in all Wellhead Protection Areas
>
> ii. Application on Parking Lots;
>   - i. In Wellhead Protection Areas A and B where the vulnerability is equal to ten (10), for medium or large parking lots;
>   - ii. In Intake Protection Zone One (1), for medium and large parking lots;
>   - iii. Where a Chloride and/or Sodium Issue has been identified, in all Wellhead Protection Areas, for medium and large parking lots.
>
> b. Future:
>
> i. Application of Salt on Roadways that would occur as the result of the approval of a Planning Act, Condominium Act, or Ontario Building Code application or upon

completion of an Environmental Assessment in accordance with the Environmental Assessment Act;

   i. In Wellhead Protection Area B where the vulnerability is equal to ten (10);
   ii. Where a Chloride and/or Sodium Issue has been identified, in all Wellhead Protection Areas except for Wellhead Protection Area A.

ii. Application on Parking Lots that would occur as the result of the approval of a Planning Act, Condominium Act or Ontario Building Code application;

   i. In Wellhead Protection Area A, for medium parking lots;
   ii. In Wellhead Protection Area B where the vulnerability is equal to ten (10), for medium or large parking lots;
   iii. Where a Chloride and/or Sodium Issue has been identified, in all Wellhead Protection Areas except for Wellhead Protection Area A, for medium and large parking lots.

The Risk Management Plan for application of salt on large and medium parking lots shall contain, as a minimum, management practices that achieve a performance standard equivalent to that of an accredited site under the Smart About Salt program to reduce the impact of de-icing activities and for new parking lots include design considerations for driving areas and sidewalks to reduce impacts to drinking water sources.

The Risk Management Plan for application of salt on roadways shall include, as a minimum, measures to ensure application rate, timing and location reduce the potential for surface water runoff and groundwater infiltration and meet the objectives of Environment Canada's Code of Practice for Environmental Management of Road Salts including identification of areas where significant threats can occur as Vulnerable Areas and management practices in these areas.

While a number of recommendations related to design and operational considerations have been included in Section 5.2. and 5.3, the list is not considered exhaustive and should not be considered to constrain future designers or implementers. Ultimately, the details of a site-specific Risk Management Plan should be defined in consultation with the Region's Risk Management Official.

- Per Official Plan policies and standard protocols routinely accepted in the Region, complete salt management plans for each development application within the study area, with the objective of minimizing the environmental impact of winter maintenance activities involving the use of de-icing salt on surface and groundwater resources. This plan should detail operational practices and strategies in three key areas: general salt usage, salt storage, and snow storage/disposal.

- Ensure that salt management plans prohibit the practice of snow and ice removal into dedicated stormwater management facilities or the natural environment buffering much of the developing area. Consider requiring that private developments build into their site maintenance plans the offsite removal of excess snow piles for storage and treatment at municipal facilities.

- Prohibit certain activities within the Parkway Well Field ICA as listed on Schedule 'B' of the Region's Official Plan (Appendix A3). While most of these activities will be effectively ruled out by zoning restrictions (e.g., salvage yards, waste treatment and disposal facilities, manufacturing facilities, etc.) some are more common in commercial settings and may be erroneously presumed as innocuous. Clearly identifying their prohibition within the study area from the outset and the associated rationale may pro-actively limit future misunderstandings. Examples include commercial dry cleaning facilities, gasoline stations and other retail establishments with gasoline sales, printing and related support activities, automotive repair facilities.

- It is noted that Category 'D' of the Region's OP Schedule 'B' also includes underground parking garages as an identified land use activity of potential sourcewater protection concern; early consultation is recommended with development proponents of the higher-density sites that might wish to implement such an approach, to ensure any associated planning or design elements area incorporated.

5.2 Design

- As per the stormwater management strategy prepared in support of the master plan / secondary plan development, maximize the at-source infiltration of “clean” runoff from roofs and pervious areas. Designing infiltration facilities to capture and recharge the first 25 mm of precipitation from all rooftops is the equivalent of 95% annual precipitation, helping to preserve pre-development recharge characteristics, contribute to shallow groundwater discharge to the receiving ESPA/PSW and deeper discharge, much of which is anticipated to eventually be conveyed to the Region’s supply source wellfields.

- Minimize the extent of ground surfaces exposed to vehicular and/or pedestrian traffic that typically requires de-icing salt applications. For example, encourage building design that includes covered parking structures and/or vehicular transit routes that minimize the need for treatment through reduction of longitudinal slopes and intersections (i.e., stop/start areas tend to require higher salt applications).

- Ensure pervious areas adjacent traveled vehicular lanes that may experience splash/spray from passing vehicles are as steeply sloped toward the traveled portion of the road as permissible, and comprised of less permeable soils (e.g., silts and clays), to encourage salt-laden runoff back to the piped and treated stormwater management system.

- Grade paved areas with sufficient slope as to encourage prompt runoff, minimizing the potential for ice formation and the associated need for excessive salt application.

- Limit snow storage capacity on individual sites, encouraging the offsite removal practices described above. For sites bordering natural areas, incorporate design measures such as engineered or natural, “living” fences to deter or eliminate the potential for simply pushing snow / ice piles beyond development limits and into natural areas.

5.3 Operational

- Minimize snow storage on higher-density residential / commercial sites, requiring as much as reasonable be transported to established facilities with treatment / reuse potential and/or receivers less sensitive to chloride loadings.

- Encourage the use of alternative de-icing chemicals where reasonable. It is understood that, despite the existence of numerous options in this regard, their adoption on a large scale is considered cost-prohibitive, especially when compared to salt, and further that they are often hard to find, two issue that are to some extent related. If a substantive market could be established for such alternative products, it could be expected that their manufacture would become more prevalent, and the costs may come down. This is an issue that is beyond the scale of the Hidden Valley Secondary Plan, the City, or event the Region to tackle on its own, but encouraging and supporting continued small steps in that direction might prove beneficial over time.

- Educate contractors and the public (e.g., through on-site signage or resident information packages) on the responsible use of de-icing salts.

- Ensure owners / contractors implement a comprehensive documentation process covering both the design and implementation of de-icing strategies. With contractually obligated legal liability in mind, there can be a tendency for contractors to over-apply products, if only to maintain the perception of responsibility. A well-documented and agreed-upon process and protocols helps reduce potential liability by establishing expectations and responsibility in advance, and providing the real-time records that can be used in any necessary defence.

- Require routine documentation from private development sites is maintained and, if required, submitted to approving agencies to illustrate continued conformance with approved salt management plans and, as necessary, enforce their implementation.

- The municipalities could consider maintaining a roster of certified, reputable contractors available as recommended service providers for private owner inquiries.

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Appendix A

Reference Material

Appendix A1

Geology and Hydrogeology Information (Stantec 2013/2014)

4.0 Local Geology and Hydrogeology

To refine the understanding of the geologic and hydrogeologic conditions within the Study Area a total of twelve (12) monitoring wells at nine (9) different locations were completed. In addition to these monitoring wells, a total of twelve (12) drive-point piezometers and three (3) staff gauges were installed within key surface water features to help better understand the linkage between the groundwater and surface systems. The monitoring locations are presented on Figure 1 and the following sections present the results and interpretation of the geology and hydrogeology with respect to the current preferred alignment for the River Road Extension.

4.1 LOCAL GEOLOGY AND HYDROSTRATIGRAPHY

Deep boreholes were completed at the locations of K-PY-OW1-12, K-PY-OW2-12, and K-PY-OW3-12 to confirm the presences of Aquitard 2/3 (ATB2/ATC1) within the Study Area and to allow a deep monitoring well to be installed within Aquifer 3 (AFD1). The following presents the results of the drilling:

- K-PY-OW1A/B-12 is located at the northern end of the Hidden Valley ESPA/PSW and coincides with the current preferred alignment of the River Road Extension (Figure 1). The subsurface conditions generally consisted of Aquifer 1 to 12.1 m (304.6 m AMSL) depth, consisting of sand to a depth of 2.1 m (314.5 m AMSL) corresponding to AFB1 with interbedded silty sand to clayey silt correspond to the Middle Maryhill Till (ATB2) to 8.2 m (308.6 m AMSL) and silty sand to sandy silt associated with AFB2 to 12.2 (304.6 m AMSL). The Lower Maryhill Till, which corresponds to Aquitard 2 (ATB3), was encountered at 12.2 m (304.6 m AMSL) and consisted of clayey silt to silt as opposed to the typical dense silty clay till that is common at other locations. Underlying the Maryhill Till, a sand to sandy silt till was encountered at 25.4 m (291.4 m AMSL) and is interpreted to correspond to the Catfish Creek Till or Aquitard 3 (ATC1/ATC2). The Catfish Creek Till extends from 25.4 m (291.4 m AMSL) to 40.3 m(276.5 m AMSL) where silty sand to sand and gravel was encountered, interpreted to correspond to Aquifer 3 (AFD1);

- K-PY-OW2A/B-12 is located within the Hidden Valley ESPA/PSW in an area mapped as an esker by Karrow (1987). The esker ridge is oriented approximately east-west with K-PY-OW2-12 situated partway up the southern flank (Figure 7). The subsurface conditions consisted of 31.0 m (282.0 m AMSL) of predominately sand and gravels associated with the esker deposit directly overlying silt to silty sand till that is interpreted as the Aquitard 3 (ATC1/ATC2). The Maryhill Till, corresponding with Aquitard 2 (ATB3), was absent at this location and the Catfish Creek Till (Aquitard 3, ATC1/ATC2) appears to have been partially reworked by glacial meltwaters and contains zones of loose sand and gravel. A sand and gravel unit interpreted to correspond to Aquifer 3 (AFD1) was encountered below the Catfish Creek Till at 40.0 m (273.0 m AMSL) and directly overlies shaley dolostone bedrock, which was encountered at 268.9 m AMSL. At this location it appears that the Maryhill Till was eroded during the deposition of the esker deposit and that glacial meltwaters have resulted in some reworking of the Catfish Creek Till, providing a window between the upper (Aquifer 1) and lower (Aquifer 3) aquifer units at this location;

- K-PY-OW3A/B-12 is located in the western portion of the Study Area near the intersection of Wilson Avenue and Goodrich Drive, approximately 350 m northeast of Production Well K32. The subsurface conditions consisted of 21.6 m of sand and sand and gravel that is interpreted as Aquifer 1 (AFB1/AFB2). Underlying the sand and gravel was 7.5 m of sandy silt till, which is at a similar elevation (303.0 m AMSL) as the Maryhill Till in the area. Below this sandy silt till unit was a sandy silt to silty sand till that extends to 289.6 m AMSL and is interpreted as Catfish Creek Till or Aquitard 3 (ATC1/ATC2). Based on geology it appears that the Maryhill Till, which corresponds to Aquitard 2 (ATB 3), is absent and the upper sandy silt till may represent a thicker sequence of Catfish Creek Till that was deposited in this area. Below the Catfish Creek Till was 4.7 m of gravel and sand and gravel that is interpreted as Aquifer 3 (AFD1);

- The shallow subsurface conditions within the Hidden Valley area at K-PY-OW4-12 to K-PY-OW8-12 consisted of silty sand to sand and gravel associated with Aquifer 1 (AFB1/AFB2) with interbedded silt to clayey silt corresponding with the Middle Maryhill Till (ATB2) present in the north at K-PY-OW1-12, K-PY-OW4-12 and K-PY-OW8-12. Toward the south and southeast AFB1 and ATB2 appear to thin and pinch out as the ground surface elevation decreases leaving AFB2 present at ground surface. At all locations, with the exception of K-PY-OW7-12, a silty clay to clayey silt till, interpreted to correspond to the Lower Maryhill Till and Aquitard 2 (ATB3), was encountered between 304 and 297 m AMSL. At K-PY-OW7-12 sand to sand and gravel was encountered to a depth of 15.9 m (291.9 m AMSL) at which point drilling was terminated due to very difficult drilling conditions. Given that Aquitard 2 (ATB3) was typically encountered at elevations of 296 to 304 m AMSL in the Hidden Valley area, the absence of this unit at K-PY-OW7-12 above a depth of 291.9 m AMSL suggest that this unit may not be present and that this location is potentially associated with the same esker deposit that was encountered at K-PY-OW2-12; and,

- Monitoring well K-PY-OW9-12 was completed near Production Well K32 at the Parkway Well Field to provide a shallow monitoring location. The subsurface conditions consisted of 6.3 m of sand, corresponding to Aquifer 1 (AFB1/AFB2), overlying a silty clay till which was encountered at an elevation of 303.0 m AMSL. The silty clay till is interpreted to correspond to the Lower Maryhill Till Aquitard 2 (ATB3).

The results of the drilling completed as part of this study, generally agree with the surficial geology mapping, with only some minor refinements as provided below and highlighted on Figure 7:

- K-PY-OW1-12: This location is mapped as glaciolacustrine-derived silty to clayey till; however, drilling at this location indicates that the shallow overburden is sand. As such, the boundary of the ice-contact stratified deposits was shifted slightly to encompass this well location. The surficial sand at this location is relatively thin (less than 2 m);

- K-PY-OW3-12: This location is mapped as glaciolacustrine-derived silty to clayey till; however, drilling at this location indicates that the shallow overburden is sand. As such, the boundary of the ice-contact stratified deposits was shifted slightly to encompass this well location;
- K-PY-OW4-12: This location is mapped as gravelly deposits; however, drilling at this location indicates that the surficial geology is clayey silt. The boundary of the ice-contact stratified deposits has been redrawn to encompass this location; and,
- K-PY-OW9-12: This location is mapped as ice-contact stratified deposits; however, drilling at this location indicated that the geology beneath the fill is sand, which is interpreted as alluvium. The boundary for modern alluvial deposits along Schneider Creek was shifted slightly to encompass this location.

4.1.1 Local Hydrostratigraphy

Within the Study Area, the local hydrostratigraphy was previously evaluated as part of the Tier 3 Water Budget and Local Area Risk Assessment (Stantec, 2009). Based on the geologic information obtained from the current study, the local hydrostratigraphic interpretation has been refined to reflect the new information. Figure 11 presents the location of the wells installed as part of this study along with the location of selected geologic cross-sections through the Study Area. Figures 12 to 13 present the geologic and hydrostratigraphic cross-section interpretations of aquifer and aquitard units within the Study Area based on the hydrostratigraphic picks of Stantec (2009) and the additional picks from the current study and surficial geologic mapping from OGS (2003).

The main refinement to the hydrostratigraphic interpretation is the absence of Aquitard 2 (ATB3) and the reworked nature of Aquitard 3 (ATC1/ATC2) at K-PY-OW2-12 and K-PY-OW3-12, and the potential absence of Aquitard 2 at K-PY-OW7-12. The borehole for monitoring well K-PY-OW2-12 was drilled through the previously mapped esker, to determine the type of material and vertical extent of the esker, in the vicinity of the ponded areas of the Hidden Valley ESPA/PSW. Results showed that the esker is over 30 m thick (Figure 12) and could extend to the northwest in the area of K-PY-OW7-12. From the mapping completed by Karrow (1987) the esker is oriented east to west (Figure 7) and appears to follow the general alignment of Hidden Valley Creek. If Aquitard 2 (ATB3) is missing and Aquitard 3 (ATC1/ACT2) is reworked along its entire length, this could result in enhanced local recharge to Aquifer 3 (AFD1) in this area.

The following sections provide a summary of the main geologic units within the Study Area, starting from Aquifer 1 and moving downward in the stratigraphic sequence.

4.1.1.1 Aquifer 1 (AFB1/ATB2/AFB2)

Aquifer 1 (AFB1/AFB2) is interpreted to be continuous across the Study Area and ranges in thickness from less to 5 m in the lower lying areas of Hidden Valley where the ground surface approaches the top of Aquitard 2 (ATB3) to over 20 m at K-PY-OW3-12 and K-PY-OW5-12 (Figure 12).

Within the Hidden Valley area AFB1 of Aquifer 1 is present in the northern areas with the Middle Maryhill Till (ATB2) generally separating Aquifer 1 into an upper (AFB1) and lower unit (AFB2). Moving south and east across the Hidden Valley area AFB1 and ATB2 thin or pinch out as the ground surface elevation decreases to the south and south east and AFB2 represents the surficial expression of Aquifer 1 (Figures 14 and 15).

The full extent of the esker deposits encountered at K-PY-OW2-12 has not been delineated but is generally interpreted to be present to the south of the West Tributary of Hidden Valley Creek. At K-PY-OW2-12 the subsurface conditions consist of sand and gravel for the full extent of Aquifer 1 (AFB1/AFB2) suggesting this represents the core of the esker deposit. To the northeast, at K-PY-OW7-12, Aquifer 1 consists of sand to a depth of 10.7 m (297.1 m AMSL) followed by sand and gravel to a depth of at least 15.9 m (292.5 m AMSL), at which point drilling was terminated due to difficult drilling conditions (Figure 12). The sand and gravel unit at K-PY-OW7-12 has been interpreted as a subsurface extension of the esker deposit in this area.

4.1.1.2 Aquitard 2 (ATB3)

Aquitard 2 (ATB3) consists of the Lower Maryhill Till and equivalent sediments and is one of the main hydrostratigraphic markers within the Waterloo Moraine. In the Study Area Aquitard 2 (ATB3) was encountered at elevations between 297 m and 303 m AMSL with typically Maryhill Till encountered at all locations except K-PY-OW2-12, K-PY-OW3-12, and K-PY-OW7 where this unit appears to be absent (Figure 12 and 13). Based on the findings at K-PY-OW2-12 it is possible that Aquitard 2 (ATB3) is missing along the entire length of the esker and in the area of K-PY-OW7-12. At K-PY-OW3-12 a sandy silt till was encountered at an elevation of 303 m AMSL, which is where Aquitard 2 (ATB3) is expected. The sandy silt till could represent an increased thickness of Catfish Creek Till (Aquitard ATC1/ATC2).

Along the north bank of the Grand River the ground surface elevation decreases with Aquitard 2 (ATB3) interpreted to be present approximately mid-way up the bank of the Grand River (Figures 12 to 15). As a result, seepage from Aquifer 1 (AFB1/AFB2) is expected along this bank.

4.1.1.3 Aquitard 3 (ATC1/AFC1/ATC2)

Aquitard 3 (ATC1/ATC2) is interpreted to be continuous across the Study Area. It is interpreted as being present at K-PY-OW2-12 (Figure 12); however it appears to be reworked and less competent compared to samples obtained from the two other deep holes drilled as part of this study. The top of Aquitard 3 (ATC1/ATC2) within the Study Area is interpreted at elevations of 295 m to 282 m AMSL with thicknesses ranging from 6 m at K-PY-OW3-12 to 15 m at K-PY-OW1-12. This thickness range is consistent with reported thickness in the area (Stantec, 2009).

Along the north bank of the Grand River, Aquitard 3 (ATC1/AFC1/ATC2) may exist along the lower portion of the bank and beneath the Grand River, and in some cases Aquifer 3 (AFD1) may be present providing seepage or discharge to the Grand River.

4.1.1.4 Aquifer 3 (AFD1)

Aquifer 3 (AFD1) corresponds with pre-Catfish Creek Till sands and gravels and is the main water supply aquifer for the Parkway Well Field. Aquifer 3 (AFD1) is interpreted to be continuous to the east beneath the Hidden Valley area where it was found to directly overlying dolostone bedrock (Figure 12).

4.1.2 Aquifer Intrinsic Susceptibility Index (ISI)

Aquifer Intrinsic Susceptibility Index (ISI) is used to indicate the susceptibility of an aquifer to contamination at a specific location. ISI values were calculated for each monitoring well installed as part of this study following the methodology presented in MOE (2006). The ISI value is dependent on two factors, the thickness of the overlying units, and the composition (sand, silt, etc.) of the overlying units. The composition of the overlying units is represented by a K-factor. Materials with lower hydraulic conductivities are represented with a higher K-factor and materials of higher hydraulic conductivity have a lower K factor. ISI values are calculated using the following equation:

$$\text{ISI value} = \Sigma\ (\text{thickness}_{unit} \times \text{K-factor}_{unit})$$

The following K-factors from MOE (2006) were used to calculate ISI values for this study:

Lithology /Geological Material	K Factor
Gravel (gravelly sand)	1*
Sand	2*
Silty Sand	3
Silt	4
Diamicton	5
Clay	6

*denotes well lithologies generally considered to represent aquifer materials

ISI values were calculated from ground surface to the upper boundary of the aquifer unit of interest (in this case Aquifer 1 or Aquifer 3). The depth to the unit of interest is depended on whether or not the aquifer was considered confined or unconfined as outlined in MOE (2006).

For the monitoring wells examined as part of this study all shallow wells (K-PY-OW1B-12, K-PY-OW2B-12, K-PY-OW3B-12, and K-PY-OW4-12 through K-PY-OW9-12) were treated as being within an unconfined aquifer and the deep monitoring wells (K-PY-OW1A-12, K-PY-OW2A-12, K-PY-OW3A-12) were treated as being within a confined aquifer.

The following ISI ranges (MOE, 2006) were used to classify the well locations according to the calculated values:

- ISI > 80 – Low intrinsic susceptibility;
- 30 < ISI < 80 – Low to moderate intrinsic susceptibility; and
- < 80 – High intrinsic susceptibility.

A summary of the ISI values calculated for each monitoring well location is presented in Table 4. For Aquifer 1 (AFB1/AFB2), ISI values ranged from 0 to 43 indicating the shallow aquifer is classified as having a High Intrinsic Susceptibility, which is not unexpected given the aquifer is unconfined and the surficial geology consists of predominantly sandy deposits. As part of Source Water Protection studies within the Region, ISI mapping has been completed for the shallow overburden aquifer (Aquifer 1) by AquaResource (2009b). For comparison purposes, the ISI values calculated for the shallow overburden aquifer (Aquifer 1) are presented on the Shallow Overburden Aquifer ISI Map as determined by AquaResource (2009b) (Figure 16). In general, the ISI values calculated as part of this study agree with the mapping generated by AquaResource (2009b) with the following exceptions noted:

- K-PY-OW3-12 – was mapped as High ISI by AquaResource (2009b); however, based on the lithology and the water level this location belongs in the Medium ISI category.

- K-PY-OW6-12 – was mapped as Medium ISI by AquaResource (2009b); however, based on the lithology and the water level this location belongs in the High ISI category.

These changes do not significantly change this study or the overall mapping generated by AquaResource (2009b).

For the deeper aquifer (Aquifer 3) ISI values at the three deep monitoring locations ranged from moderate at K-PY-OW2-12 (ISI = 68) to low at K-PY-OW1-12 and K-PY-OW3-12 (ISI = 178 and 104, respectively). One of the main reasons for the moderate rating at K-PY-OW2-12 is due to the absence of the Lower Maryhill Till (ATB2). Figure 17 presents the ISI mapping for Aquifer 3 (AFD1) from AquaResource (2009b). The only area where the ISI mapping would change as a result of the recent borehole drilling is K-PY-OW2-12 and possibly K-PY-OW7-12 where

Aquitard 2 (ATB3) was absent and an ISI score (68) of medium was calculated. The extent of the medium ISI zone in this area is dependent on the presence of Aquitard 2 (ATB3). If Aquitard 2 (ATB3) is absent beneath the esker, then the medium ISI zone could extend to the west along the interpreted alignment of the esker.

4.2 HYDROGEOLOGY

Groundwater and surface water level monitoring was completed within the Study Area between October 2012 and July 2012. The data consists of water levels from twelve (12) drive-point piezometers and eighteen (18) monitoring wells. The water level hydrographs for all monitoring locations are presented in Figures 18 to 22, along with the available precipitation data from the Kitchener-Waterloo Climate Station (Station ID: 6144239) and pumping data from the Parkway Well Field. Additional hydrographs for each of the nested wells are presented in Appendix H.

The following sections detail groundwater flow, vertical hydraulic gradients, response to pumping at the Parkway Well Field, and response to precipitation events within the various hydrostratigraphic units within the Study Area.

4.2.1 Groundwater Flow

4.2.1.1 Aquifer 1 (AFB1/AFB2)

Groundwater levels were monitored within Aquifer 1 (AFB1/AFB2) at K-PY-OW1B-12 (ATB2), K-PY-OW3B-12 (AFB1/AFB2), K-PY-OW4-12 (ATB2/AFB2), K-PY-OW5-12 (AFB2), K-PY-OW6-12 (AFB2), K-PY-OW7-12 (AFB2), and K-PY-OW8-12 (AFB2), and PK1D-95 as well as the drive-point piezometers.

Figure 24 presents the interpreted water table elevation and groundwater flow within Aquifer 1 (AFB1/ARB2) on July 1 2012. While shallow groundwater levels appear to be locally influenced by topography, the general trend is for groundwater to flow towards Schneider Creek in the western portion of the Study Area and towards the Grand River in the eastern portion of the Study Area. Based on the interpreted elevation of Aquitard 2 (ATB3), seepage from Aquifer 1 (AFB1/AFB2) is interpreted along the bank of the Grand River upstream of the Hidden Valley Intake with the ponds located within the floodplain to the south of the Hidden Valley residential development interpreted as the water table expression of Aquifer 1 (AFB1/AFB2). This overall interpretation of flow is generally consistent with the more regional interpretation prepared by AquaResource (2009a).

In the western portion of the Study Area near the Parkway Well Field, Schneider Creek is interpreted to be very close to the base of Aquifer 1 (AFB1/AFB2) and as a result discharge conditions may be expected along this portion of the Creek (Figure 12). Water level data from DP5-11 confirms this interpretation with upward vertical gradients beneath the creek indicating groundwater from Aquifer 1 (AFB1/AFB2) is discharging to this section of Schneider Creek (Figure 22).

In the Hidden Valley area, the ground surface elevation along the West Tributary of Hidden Valley Creek is very close to the top of Aquitard 2 (ATB3). Upward vertical gradients are evident along this channel at DP2-11 (-0.01) with the highest upward gradients noted at DP1-13 (-0.15), indicating groundwater from Aquifer 1 (AFB1/AFB2) provides some local baseflow over these reaches (Table 5). To the south of the open water/march area, in vernal Ponds A, B, and C, vertical gradients are generally downward at DP6-11, DP7-11, DP8-11, DP9-11, and DP10-11, ranging from 0.01 to 0.14, suggesting downward flow and discharge from these areas to Aquifer 1 (AFB1/AFB2) (Figure 22; Table 5). Along the margins of the open water/marsh area at DP11-12 and DP13-12 slight upward vertical gradients are evident (-0.03 to -0.10) suggesting potential local recharge on the upgradient margins of this area (Figure 22; Table 5).

Drive-point DP3-11 was installed within the North Tributary of Hidden Valley Creek, just south of the crossing beneath Highway 8. At this location an upward vertical gradient is generally present suggesting shallow groundwater discharge to this portion of the tributary (Figure 22).

Drive-point DP12-12 was installed within the isolated wetland pocket in the northeast corner of the Hidden Valley area. Groundwater and surface water elevations were similar at this location with no clear vertical gradients observed (Figure 22). In comparison to groundwater levels at K-PY-OW5-12 (302.2 m AMSL), the water levels at DP12-12 are significantly higher at approximately 312 m AMSL suggesting that surface water at this location is perched and not connected with groundwater levels within Aquifer 1 (AFB1/AFB2).

4.2.1.2 Aquifer 3 (AFD1)

Groundwater levels were monitored within the lower hydrostratigraphic units including Aquifer 3 (AFD1) at monitoring wells K-PY-OW1A-12, K-PY-OW2A-12, and K-PY-OW3A-12, and PK1B-95, and within the bedrock at PK1A-95 and PK9A-96 (at interface with overlying AFD1).

Figure 25 shows the measured groundwater elevation and interpreted potentiometric surface based on data from July 1, 2012. These data suggest that a local groundwater flow divide exists within the vicinity of the Hidden Valley ESPA/PSW. Groundwater on the western portion of this divide flows to the west towards the Parkway Well Field under pumping conditions, while groundwater on the eastern portion of this divide is interpreted to flow towards the Grand River. Based on the available data the exact position of this flow divide cannot be located. In comparison to the regional mapping produced by AquaResource (2009a), which is presented in Figure 10 and was based on limited detailed data in the area of Hidden Valley, it appears that a portion of the flow from the Hidden Valley area is captured by the Parkway Well Field. This is generally consistent with the wellhead protection area mapping (Figure 6), which indicates a portion of WPSA-7 and WPSA-8 extend into this area.

Groundwater elevations in Aquifer 3 (AFD1) were lowest at PK1A/B-95 near the Parkway Well Field, with the lowest recorded level (290.84 m AMSL) at PK1A-95 on July 12, 2012. The maximum recorded groundwater elevation (297.03 m AMSL) was recorded at K-PY-OW-2A-12 on June 3, 2012. For comparison purposes the hydrographs for all of the monitoring locations in Aquifer 3 (AFD1) are presented on single graphs for the full monitoring period (Figure 20) and a more focused period during May to July 2012 (Figure 21).

4.2.1.3 Vertical Hydraulic Gradients

Vertical hydraulic gradients at all monitoring wells between Aquifer 1 (AFB1/AFB2) and Aquifer 3 (AFD1) were downward, ranging from 0.28 m/m at K-PY-OW2-12 to 0.77 m/m at K-PY-OW3-12 (Table 5). The fact that K-PY-OW2-12 had the smallest vertical hydraulic gradient between Aquifer 1 (AFB1/AFB2) and Aquifer 3 (AFD1) is likely a reflection of the absence of Aquitard 2 (ATB3) and the reworked nature of Aquitard 3 (ATC1/2) at this location, suggesting increased vertical hydraulic connection. One of the strongest downward vertical gradients was observed at K-PY-OW3-12 where Aquitard 2 (ATB3) was absent. The fact that a strong downward gradient exists at this location suggests that the potential increased thickness of Aquitard 3 (ATC1) is limiting downward groundwater flow and hydraulic connections between Aquifer 1 (AFB1/AFB2) and Aquifer 3 (AFD1) in this area.

Downward vertical hydraulic gradients at K-PY-OW2-12, coupled with downward vertical hydraulic gradients at the drive-point piezometers within the ponded areas of the Hidden Valley ESPA/PSW suggest that leakage from the ponded area and vernal ponds will result in the downward flow of water to Aquifer 1 (AFB1/AFB2) and subsequent recharge to Aquifer 3 (AFD1) through leakage or windows within Aquitard 2 (ATB3). Based on the water level data and vertical gradients, the ponded area and vernal ponds (Pond A, B, and C) are interpreted to be sustained primarily by surface water runoff and spring melt conditions.

4.2.1.4 Response to Pumping at the Parkway Well Field

At all of the monitoring locations within Aquifer 3 (AFD1) (K-PY-OW1A-12, K-PY-OW2A-12, K-PY-OW3A-12, PK9A-96, PK1A-95) a direct hydraulic response to pumping at the Parkway Well Field is evident. The clearest response to pumping can be seen on June 2 and 3, 2012 when Production Wells K31 and K32 were off and less than 50% of the average volume of water was pumped from K33 (Figure 20). Over this time period a rapid short-term recovery at all of the deep monitoring wells was evident with the following recoveries observed:

- 3.79 m at PK1A-95 located within 200 m of Production Wells K32;
- 1.23 m at PK9A-96 located within 1,230 m of Production Wells K32;
- 1.03 m at K-PY-OW2A-12 located within 1,550 m of Production Wells K32;
- 0.85 m at K-PY-OW1A-12 located within 1,860 m of Production Wells K32; and,
- 0.47 m at K-PY-OW3A-12 located within 300 m of Production Wells K32;

The recovery observed at K-PY-OW-3A-12 is smaller than would be expected based on its proximity to the Parkway Well Field. Monitoring Well K-PY-OW3A-12 is installed about 7 m higher (286 to 287 m AMSL) than the production wells at the Parkway Well Field and therefore may be partially disconnected from the more permeably portions of Aquifer 3 (Figure 12).

This response to pumping is consistent with historical shutdown tests in the area by Terraqua (1998) and suggests that the zone of influence from the Parkway Well Field extends beneath the Hidden Valley area, at least as far east as K-PY-OW2A-12.

An overall decreasing trend in groundwater levels with Aquifer 3 (AFD1) is evident from late April 2012 until the end of June 2012. The largest decrease in water level was observed at K-PY-OW3-12 (approximately 1.25 m) and the smallest decrease was observed at K-PY-OW2A-12 and PK9A-96 (approximately 0.75 m). This decreasing trend is interpreted to be consistent with typical annual variations in water levels, which will be confirmed as part of future monitoring.

4.2.1.5 Parkway Well Field Capture Zone Analysis

Capture zone analysis for the Parkway Well Field was originally completed as part of the Parkway Well Field study in 1998 (Terraqua, 1998) and is used as the basis for the Region's WPSAs presented in their current Regional Official Plan (Region, 2010). The WPSA-4, WPSA-7, and WPSA-8 (Figure 6) from the Official Plan correspond to the 2-year, 10-year, and steady-state capture zones (Terraqua, 1998). From the capture zone analysis completed by Terraqua (1998) the eastern extent of the capture zone for the Parkway Well Field extends into the western portion of Hidden Valley. It is important to note that these capture zones represent the horizontal travel times within Aquifer 3 (AFD1) and are not surface based capture zones. Precipitation that recharges Aquifer 1 (AFB1/AFB/2) within this area will either infiltrate to Aquifer 3 (AFD1) by leakage through Aquitard 2 (ATB3) and 3 (ATC1/ATC2) or contribute to discharge to the Grand River and tributaries of Schneider and Hidden Valley Creeks.

The Region is currently completing the Tier 3 Water Budget and Local Area Risk Assessment project which will result in refined capture zones for the well fields. The results of this study should be used to up-date the geologic and hydrogeologic data for the Parkway Well Field area.

4.2.1.6 Response to Precipitation Events

Daily precipitation and mean daily temperature data between October 2011 and July 2012 was obtained from the Environment Canada website and was downloaded in digital format. The nearest Environment Canada climate station was located approximately 5.5 km northwest of the Study Area at the Waterloo-Wellington International Airport.

A review of the climate data for the study period (October 2011 to June 2012) indicates that the average monthly temperature was consistently above the long term monthly averages from 1971-2000 at the Waterloo-Wellington International Airport. Additionally, below average precipitation was recorded between January 2012 and May 2012 and little to no spring freshet conditions were experienced due to the below average snowfall and below average precipitation. Monthly average daily temperature and precipitation data are presented in Table 6. Data collection was terminated in early July 2012, as such monthly comparisons are only provided up to June 2012.

Monitoring wells screened within Aquifer 3 (AFD1) do not show any apparent response to individual precipitation events (Figures 20 and 21).

Groundwater levels at K-PY-OW9-12 and PK1C-95 completed within Aquitard 2 (ATB3) show a decreasing groundwater elevation trend from May 2012 to July 2012 of approximately 0.25 m and a variable response to precipitation events (Figure 19). K-PY-OW9-12 shows a response to the large precipitation event at the beginning of June 2012 whereas PK1C-95, which is also located in Aquitard 2 (ATB3), does not show a response. This is likely a reflection of K-PY-OW9-12 being installed at the top of Aquitard 2 (ATB3), whereas the top of the screen at PK1C-95 is approximately 4 to 5 m below the top of Aquitard 2 (ATB3).

None of the shallow monitoring wells showed a response to small precipitation events (< 10 mm); however, they all showed a response to the large precipitation event on June 1, 2012 (~ 40 mm), with the exception of K-PY-OW1B-12, K-PY-OW3B-12, OW5-12, and PK9B-96 (Figure 18 and 19). A review of the installation details (Table 2) shows that wells that did not respond to the precipitation event are either installed in low hydraulic conductivity material associated with the Middle Maryhill Till (K-PY-OW1B-12) or where the unsaturated zone reaches thicknesses of up to 17 m.

4.2.2 Aquifer Hydraulic Conductivity

Hydraulic conductivity testing at wells installed within Aquifer 1 (AFB1/AFB2) included: K-PY-OW3B-12, K-PY-OW4-12, K-PY-OW5-12; K-PY-OW6-12; K-PY-OW7-12; and K-PY-OW8-12. Hydraulic conductivity values ranged from $3x10^{-5}$ m/s to $4x10^{-7}$ m/s which is at the low end of the range reported in the Tier 3 Water Budget and Local Area Risk Assessment (Stantec, 2009). Near surface hydraulic conductivity testing was performed at six (6) locations within the Hidden Valley ESPA/PSW (Figure 1; Table F-1) using a Guelph Permeameter. The results of this testing indicated that near surface hydraulic conductivity values were within a narrow range of $7x10^{-7}$ m/s at GP1-12 to $3x10^{-6}$ m/s GP5-12 and are similar to the ranges from the monitoring wells completed within Aquifer 1 (AFB1/AFB2). Guelph Permeameter location GP1-12 was the only location installed within the sandy silt till (Unit 5B of Figure 4) of Aquitard 1 (ATB1) and had a hydraulic conductivity of $7x10^{-7}$ m/s. All other locations were installed within ice-contact deposits of sand and/or sand and gravel and have similar hydraulic conductivities in the range of $1x10^{-6}$ to $3x10^{-6}$ m/s. Hydraulic conductivity testing completed at K-PY-OW9-12 (the only monitoring well installed within Aquitard 2) resulted in a hydraulic conductivity estimate of $3x10^{-9}$ m/s, which is within the range typically found throughout the Region for this unit.

Hydraulic conductivity testing completed at the three (3) deep monitoring wells installed in Aquifer 3 (AFD1) as part of this study, K-PY-OW1A-12, K-PY-OW2A-12, K-PY-OW3A-12, had estimated hydraulic conductivity values of $8x10^{-6}$ m/s to $4x10^{-5}$ m/s. These values are slightly lower than those previously reported for Aquifer 3 (AFD1) by Terraqua (1995) of $2x10^{-3}$ m/s to $9x10^{-5}$ m/s. The values reported by Terraqua (1995) were estimated from pumping test data and as a result will be reflective of the more permeable portions of the aquifer (Rovey and Cherkauer, 1995).

4.2.3 Summary

The new data collected as part of this study provides further refinement to the interpreted geologic and hydrogeologic conditions. Given the elevation of Schneider Creek and Hidden Valley Creek within the Study Area is close to the top of Aquitard 2 (ATB3), shallow groundwater from Aquifer 1 (AFB1/AFB3) is interpreted to provide local discharge to reaches of both surface water features. In the Hidden Valley ESPA the beaver dam has a significant impact on shallow groundwater flow and stream discharge conditions. In the area of ponded water created by the dam, downward vertical gradients were observed confirming that surface water is recharging Aquifer 1 (AFB1/AFB2) in this area. Based on the drilling data from this study a window in Aquitard 2 (ATB3) is interpreted in the area of the esker that extends through the Hidden Valley ESPA, and in the area near K-PY-OW3-12. Where these windows exist, increased leakage from Aquifer 1 (AFB1/AFB2) to Aquitard 3 (AFD1) may occur. Considering the hydraulic response to pumping at the Parkway Well Field, water that infiltrated to Aquifer 3 (AFD1) in this area is interpreted to be captured by the Parkway Well Field.

4.3 GROUNDWATER QUALITY

As part of the hydrogeologic assessment, groundwater quality monitoring was completed in April 2012 to document existing water quality conditions and to initiate the baseline monitoring program. Water quality results are presented in Table 7 with copies of the laboratory Certificates of Analysis included in Appendix I. The following presents a review of water quality data.

4.3.1.1 Groundwater Quality Aquifer 1 (AFB1/AFB2)

Groundwater quality within Aquifer 1 (AFB1/AFB2) meets the ODWS for all parameters expect hardness, which is typical of groundwater from southern Ontario, and chloride, sodium, DOC, and sulphate at select locations.

Chloride and sodium concentrations were above the ODWS of 250 mg/L and 200 mg/L, respectively, at K-PY-OW1B-12, K-PY-OW2B-12, and K-PY-OW3B-12, and slightly elevated at K-PY-OW6-12 (215 mg/L chloride and 97 mg/L sodium) and K-PY-OW7-12 (145 mg/L chloride and 129 mg/L sodium). Chloride and sodium concentrations were highest at K-PY-OW1B-12 (972 mg/L chloride and 533 mg/L sodium), located on Hidden Valley Road adjacent to Highway 8 with the next highest concentrations a K-PY-OW3B-12 (477 mg/L chloride and 274 mg/L sodium) located along Goodrich Drive. At K-PY-OW2B-12, chloride and sodium concentrations were 312 mg/L and 212 mg/L, respectively. The elevated chloride concentrations at K-PY-OW1B-12 and K-PY-OW6-12 are expected to be associated with winter road salting of Highway 8 and to a lesser degree Hidden Valley Road, while the elevated concentrations at K-PY-OW3B-12 are interpreted to be due to winter road salting on Goodrich Drive and Wilson Avenue. The elevated chloride and sodium concentrations at K-PY-OW2B-12 are surprising as this location is well removed from the road network and is considerably higher than other shallow monitoring locations within the Hidden Valley area where chloride concentrations typically range from 6 to 29 mg/L. It is interpreted that the source of the elevated sodium and chloride concentrations at K-PY-OW2B-12 and K-PY-OW7-12 is related to either surface water infiltration within the Hidden Valley area or up gradient sources that are connected to the esker deposits in the area of Wabanaki Drive and Fairway Road.

Iron was generally below the ODWS within Aquifer 1 (AFB1/AFB2) at all locations except K-PY-OW2B-12 (0.69 mg/L). Manganese was slightly elevated above the ODWS at all locations with the exception of K-PY-OW1B-12, K-PY-OW3B-12, and K-PY-OW7-12 with concentrations ranging from 0.06 mg/L to 0.35 mg/L. Elevated iron and manganese concentrations are interpreted to be associated with natural sources and indicate that portions of Aquifer 1 (AFB1/AFB2) are transitioning from aerobic to moderately anaerobic conditions.

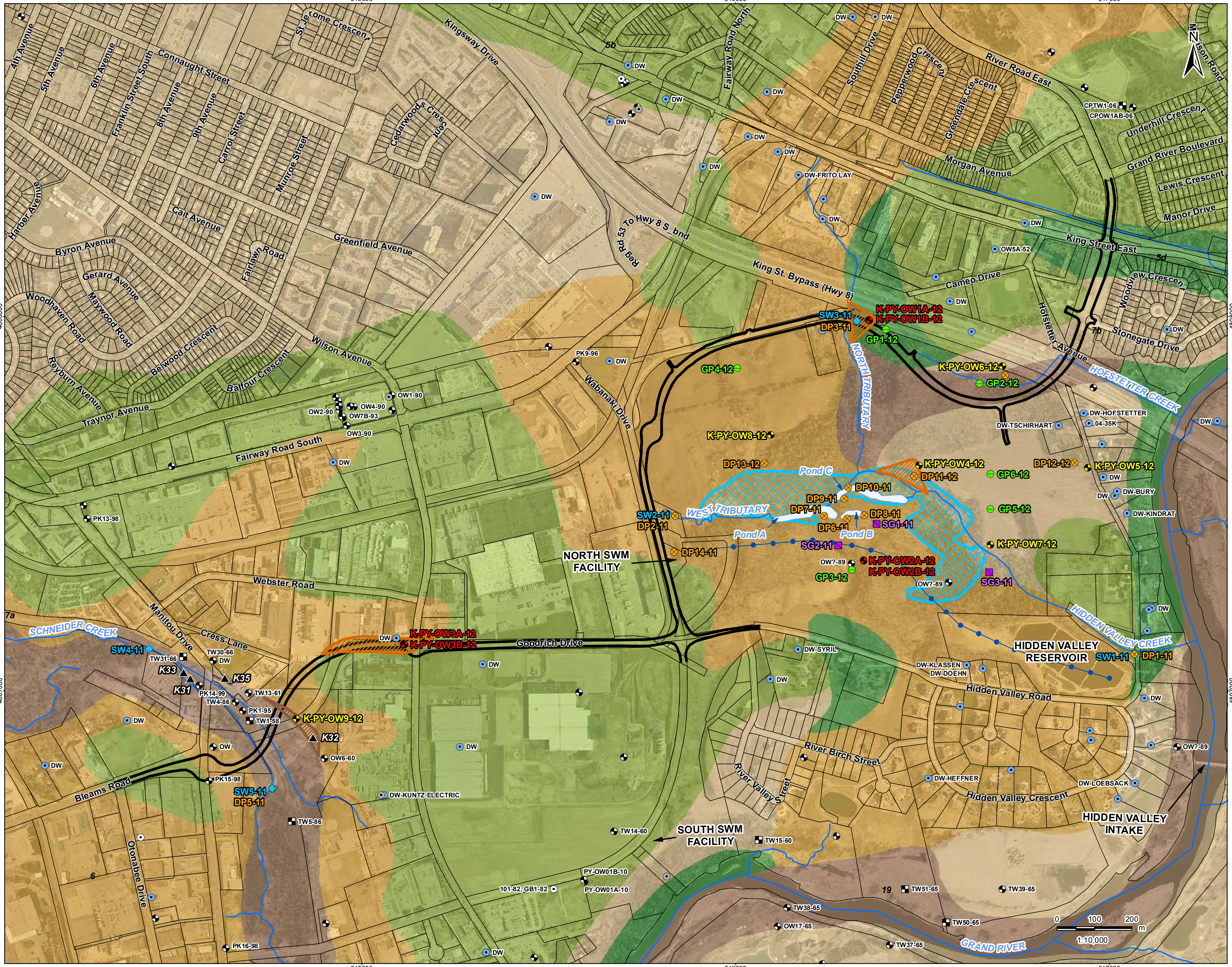
Nitrate was observed at six of the shallow monitoring wells at concentrations ranging from 1.0 mg/L at K-PY-OW1B-12 and K-PY-OW4-12 to a high of 5.2 mg/L at K-PY-OW8-12. The locations with the higher nitrate concentrations are generally associated with agricultural areas with the exception of K-PY-OW3B-12 which is located within a road right-of-way.

4.3.1.2 Groundwater Quality Aquifer 3 (AFD1)

Groundwater quality within Aquifer 3 (AFD1) meets the ODWS for all parameters expect hardness, which is typical of groundwater from southern Ontario, sulphate at K-PY-OW1A-12, and chloride and sodium at K-PY-OW2A-12 and K-PY-OW3A-12. Iron exceeded the ODWS at K-PY-OW1A-12 and manganese exceeded the ODWS at K-PY-OW3A-12.

Chloride concentrations are highest at K-PY-OW2A-12 and K-PY-OW3A-12 ranging from 388 mg/L to 677 mg/L, respectively, and are higher than within Aquifer 1 (AFB1/AFB2) at these locations. At both of these monitoring locations Aquitard 2 (ATB3) is absent and Aquitard 3 (ATC1/ATC2) is interpreted have been reworked by glacial meltwaters. The sodium and chloride data supports the hydrogeologic data indicating that these areas represent windows for the downward flow of groundwater from Aquifer 1 (AFB1/AFB2) to Aquifer 3 (AFD1). In comparison, the highest chloride concentration within Aquifer 1 (AFB1/AFB2) was observed at K-PY-OW1A-12 (972 mg/L) whereas the chloride concentrations within Aquifer 3 (AFD1) at this location was 8.5 mg/L, indicating Aquitard 2/3 provides effective protection to groundwater quality within Aquifer 3 (AFD1). This is consistent with the geologic data for this location which identified the presence of both Aquitard 2 (ATB3) and Aquitard 3 (ATC1/ATC2).

Sulphate concentrations within Aquifer 3 (AFD1) range from 31 mg/L to 70 mg/L at K-PY-OW2A-12 and K-PY-OW3A-12 to 534 mg/L at K-PY-OW1A-12. The sulphate concentrations at K-PY-OW2A-12 and K-PY-OW3A-12 are typical of groundwater quality from Aquifer 1 (AFB1/AFB2) and together with the elevated sodium and chloride concentrations support the interpretation of the downward flow of water from Aquifer 1 (AFB1/AFB2) to Aquifer 3 (AFD1). In comparison, the sulphate concentrations at K-PY-OW1A-12 are typical of groundwater from Aquifer 3 (AFD1) where Aquitard 2/3 is present.



Legend

- Production Well
- Deep Monitoring Well (Stantec, 2012)
- Shallow Monitoring Well (Stantec, 2012)
- Drive-Point Piezometer (Stantec 2011/2012)
- Guelph Permeameter (Stantec, 2012)
- Surface Water Monitoring Location (Stantec, 2011)
- Staff Gauge (Stantec, 2011)
- Observation Well
- Test Hole
- Water Supply Well
- Unknown Well Type
- Abandoned Well
- Proposed Road Alignment
- Approximate Esker Location (Karrow, 1987)
- Watercourse
- Ponded Area (Stantec, 2011)
- Vernal Pond (LGL, June 2009)
- Parcel Fabric

Surficial Geology

- 19: Modern alluvial deposits
- 7a: Sandy deposits
- 7b: Gravelly deposits
- 6: Ice-contact stratified deposits
- 5b: Stone-poor, carbonate-derived silty to sandy till
- 5d: Glaciolacustrine-derived silty to clayey till

Revised Surficial Geology

- 19: Modern Alluvial Deposits
- 6: Ice-contact stratified deposits

Notes

1. Coordinate System: NAD 1983 UTM Zone 17N
2. Base features produced under license with the Ontario Ministry of Natural Resources © Queen's Printer for Ontario, 2011.
3. Aerial imagery provided by First Base Solutions, Region of Waterloo, 2009.
4. Parcel fabric © Region of Waterloo, 2009.
5. Surficial geology produced by the Ontario Geological Survey 2003. Surficial geology of Southern Ontario; Ontario Geological Survey, MRD 128.

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Client/Project
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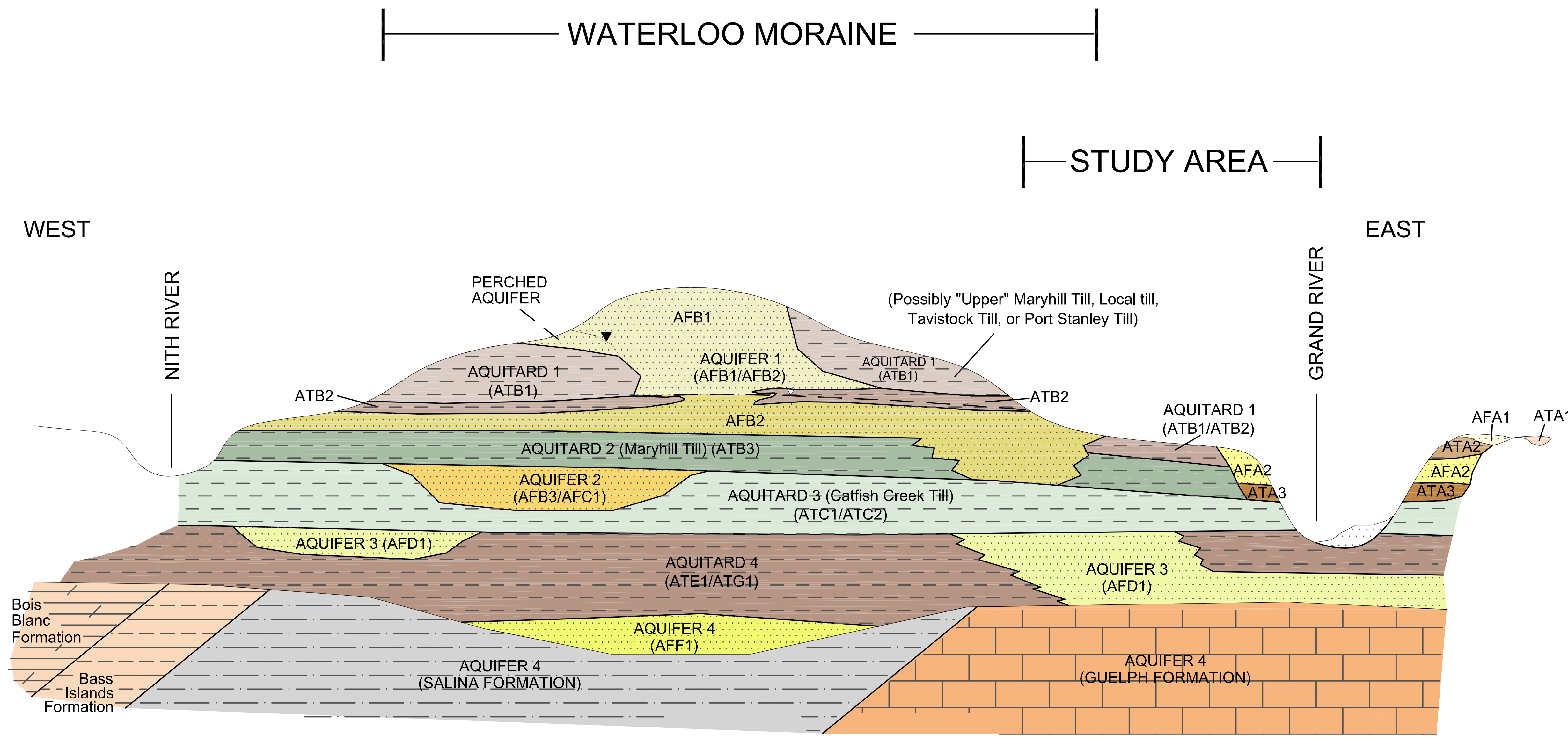
River Road Extension
King Street to Manitou Drive, Kitchener, Ontario

Figure No.
7

Title
Surficial Geology

\\cd1004-f06\Work_group\01609\active\160900687_River_Rd_Hydrogeo\planning\drawing\MXD\HydroG_Assess\160900687_HG_Fig07_SGeo.mxd
Revised: 2013-03-28 By: ccoghlan



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Legend

Aquifer
Aquitard
Perched Water Table
Regional Water Table

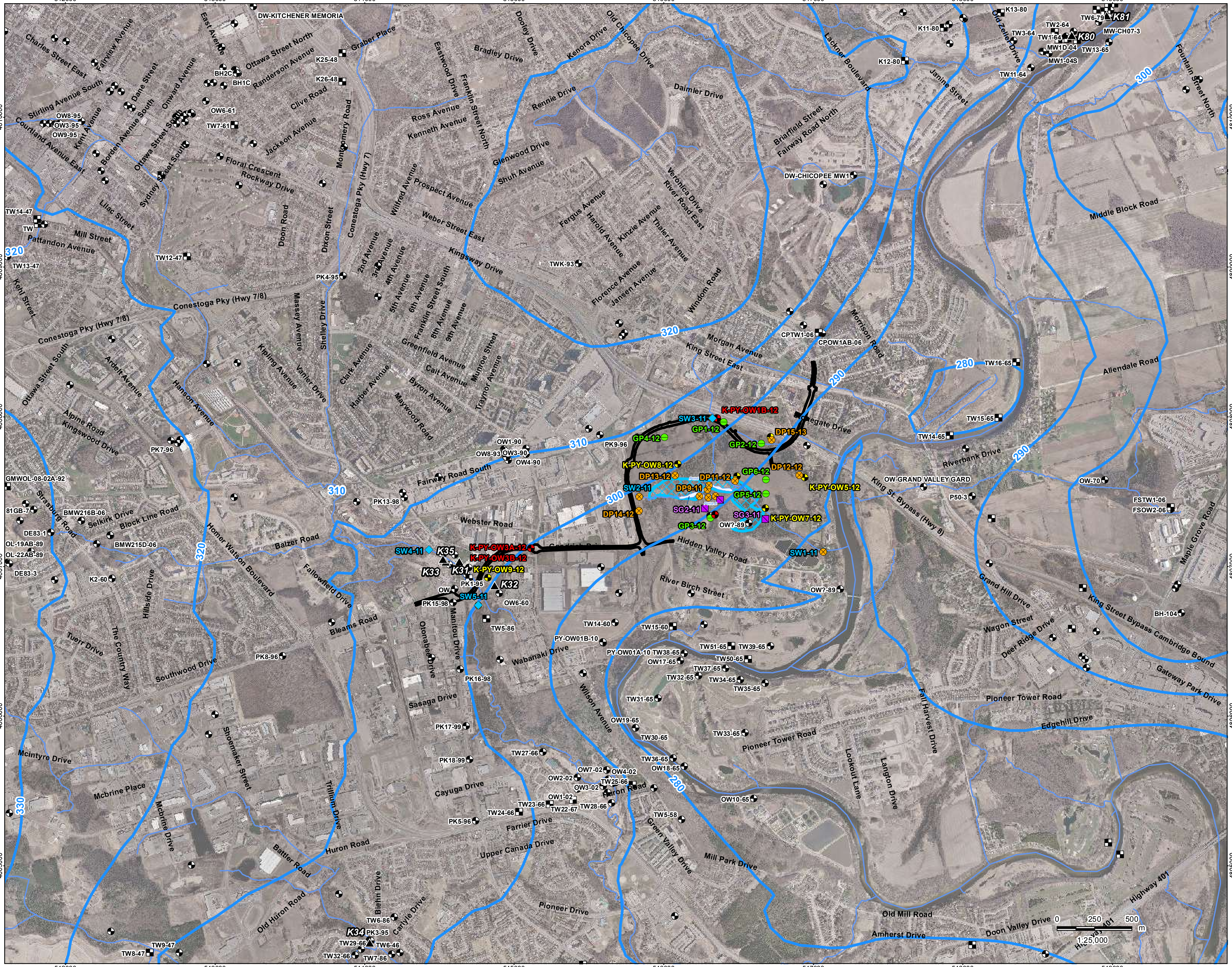
Notes

1. Hydrostratagraphic model after Terraqua (1995).
2. Geologic Sequences from BAJC (2005).

Client/Project
Stage 1 Hydrogeology Study
River Road Extension
King Street to Manitou Drive, Kitchener, Ontario

Figure No.
8

Title
Hydrostratigraphic Framework - Waterloo Moraine



Legend

- Production Well
- Deep Monitoring Well (Stantec, 2012)
- Shallow Monitoring Well (Stantec, 2012)
- Drive-Point Piezometer (Stantec 2011/2012)
- Guelph Permeameter (Stantec, 2012)
- Surface Water Monitoring Location (Stantec, 2011)
- Staff Gauge (Stantec, 2011)
- Observation Well
- Test Hole
- Groundwater Contour (mAMSL)
- Proposed Road Alignment
- Watercourse
- Ponded Area (Stantec, 2011)
- Vernal Pond (LGL, June 2009)

0 250 500 m
1:25,000

Notes

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3. Orthoimagery © Region of Waterloo, 2009.
4. Parcel fabric © Region of Waterloo, 2009.
5. Groundwater contours from AquaResource, Mapping of Shallow and Deep Potentiometric Surfaces, March 2009. Contours based on various data sources as described in AquaResource, 2009.

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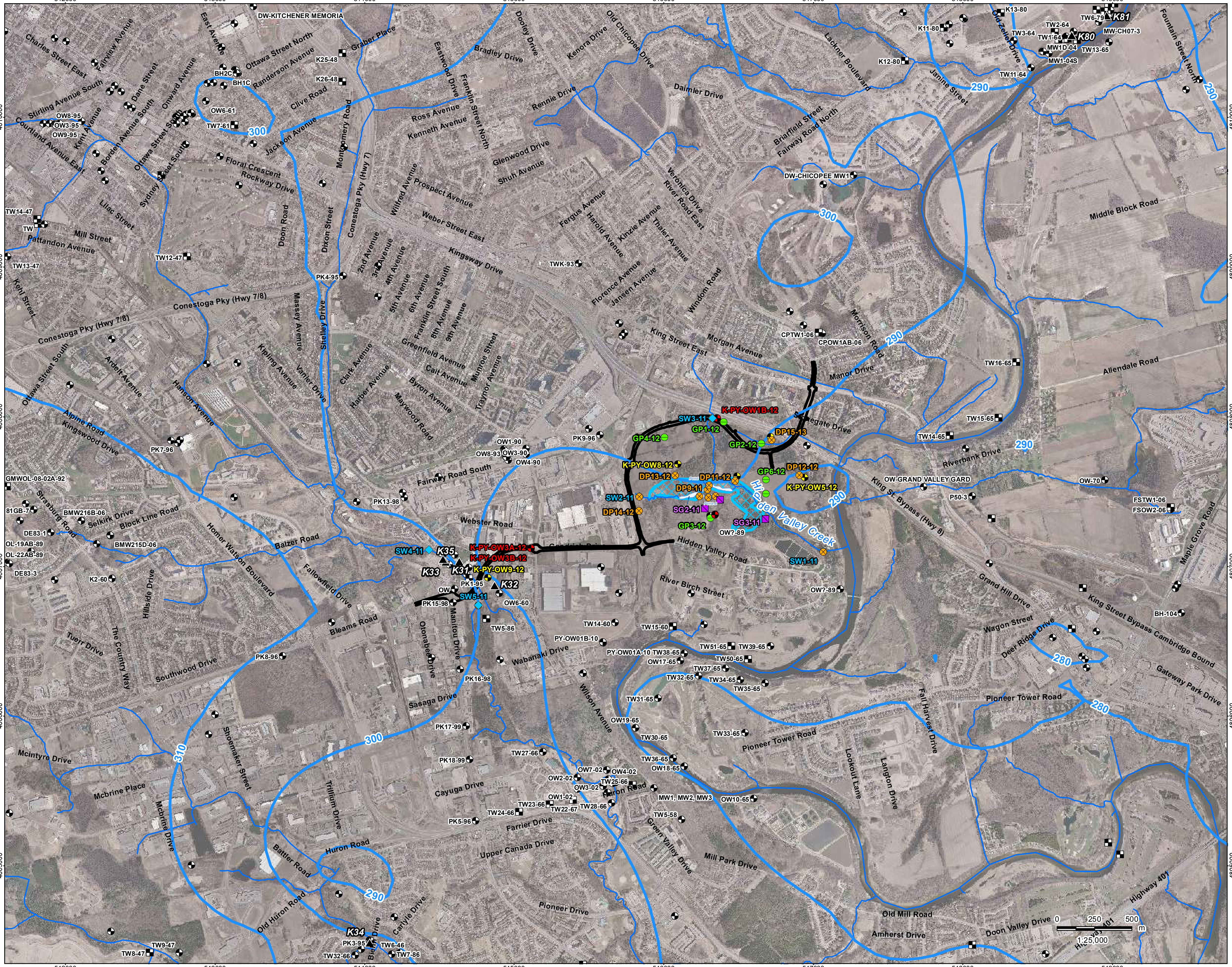
River Road Extension
King Street to Manitou Drive, Kitchener, Ontario

Figure No.
9

Title
Regional Groundwater Flow Aquifer 1 (AFB1 / AFB2)

\\cd1004-f06\Work_group\01609\active\160900687_River_Rd_Hydrogeo\planning\drawing\MXD\HydroG_Assess\160900687_HG_Fig09_GrdwFlowAquifer1.mxd
Revised: 2013-03-28 By: ccoghlan



Legend

- Production Well
- Deep Monitoring Well (Stantec, 2012)
- Shallow Monitoring Well (Stantec, 2012)
- Drive-Point Piezometer (Stantec 2011/2012)
- Guelph Permeameter (Stantec, 2012)
- Surface Water Monitoring Location (Stantec, 2011)
- Staff Gauge (Stantec, 2011)
- Observation Well
- Test Hole
- Groundwater Contour (mAMSL)
- Proposed Road Alignment
- Ponded Area (Stantec, 2011)
- Watercourse
- Vernal Pond (LGL, June 2009)

Notes

1. Coordinate System: NAD 1983 UTM Zone 17N
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4. Parcel fabric © Region of Waterloo, 2009.
5. Groundwater contours from AquaResource, Mapping of Shallow and Deep Potentiometric Surfaces, March 2009. Contours based on various data sources as described in AquaResource, 2009.

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River Road Extension
King Street to Manitou Drive, Kitchener, Ontario

Figure No.
10

Title
Regional Groundwater Flow Aquifer 3 (AFD1)

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Revised: 2013-03-28 By: ccoghlan

Legend

- Production Well
- Deep Monitoring Well (Stantec, 2012)
- Shallow Monitoring Well (Stantec, 2012)
- Drive-Point Piezometer (Stantec 2011/2012)
- Guelph Permeameter (Stantec, 2012)
- Surface Water Monitoring Location (Stantec, 2011)
- Staff Gauge (Stantec, 2011)
- Observation Well
- Test Hole
- Water Supply Well
- Unknown Well Type
- Abandoned Well
- Cross-Section Location
- Proposed Road Alignment
- Watercourse
- Ponded Area (Stantec, 2011)
- Vernal Pond (LGL, June 2009)
- Parcel Fabric

Notes

1. Coordinate System: NAD 1983 UTM Zone 17N
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Stage 1 Hydrogeology Study
River Road Extension
King Street to Manitou Drive, Kitchener, Ontario

Figure No.
11

Title
Cross-Section Locations

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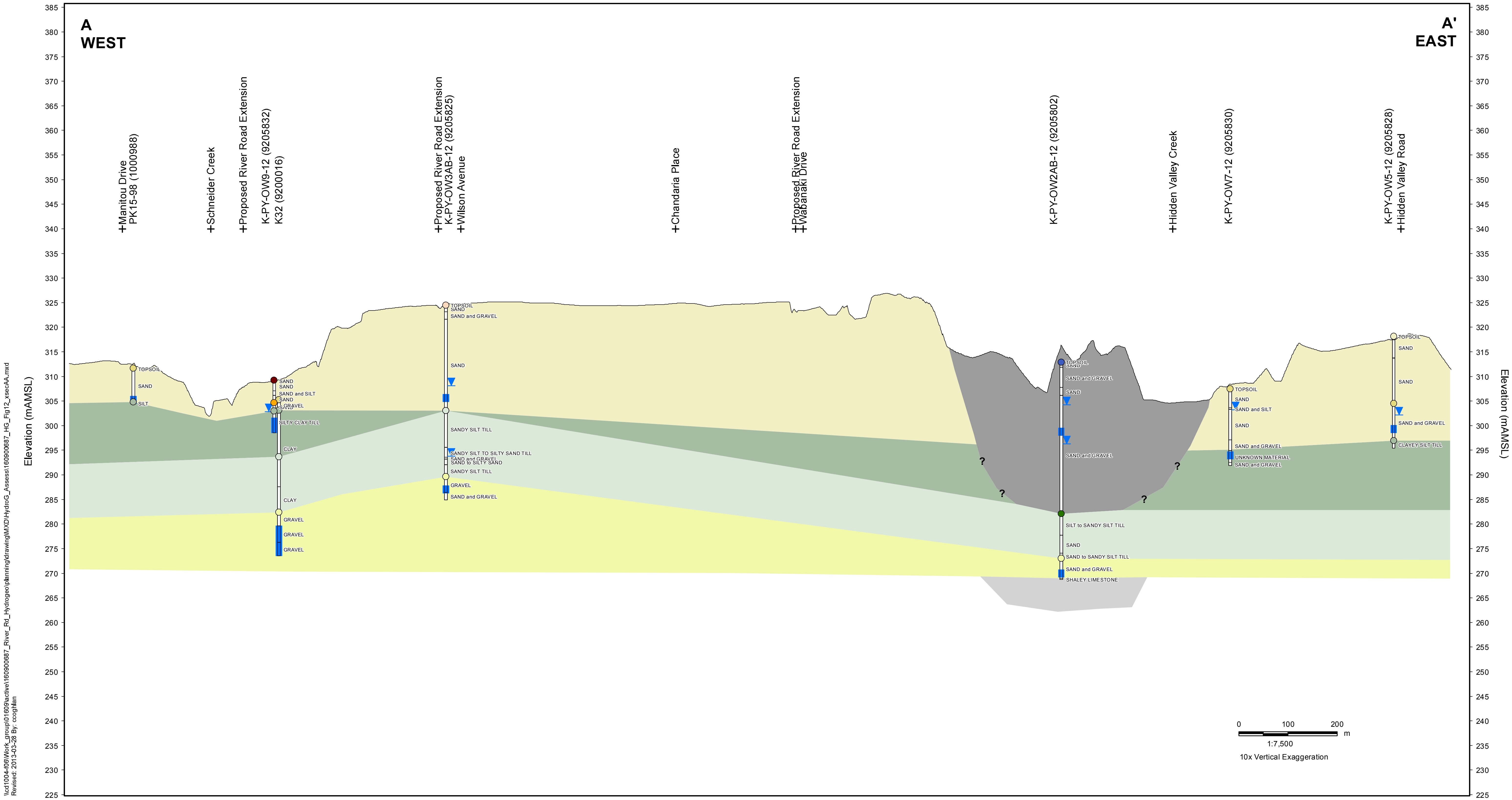

March 2013
160900687

Legend

- OW1-12 — Well ID
- Sand — Stratigraphy
- Water Level (July 1, 2012)
- Well Screen
- + Crossing
- O Formation Pick
- Esker
- ATB1 - Upper Maryhill, Port Stanley Till (Aquitard 1)
- AFB1/AFB2 - Upper/Middle Moraine Stratified Sediments & Equivalents (Aquifer 1)
- ATB2 - Middle Maryhill Till and Equivalents (Aquifer 1)
- ATB3 - Lower Maryhill Till and Equivalents (Aquitard 2)
- ATC1/ATC2 - Catfish Creek Till (Aquitard 3)
- AFD1 - Pre-Catfish Sand & Gravel (Aquifer 3)
- ATE1 - Canning Drift Till (Aquitard 4)
- Bedrock - Salina Formation

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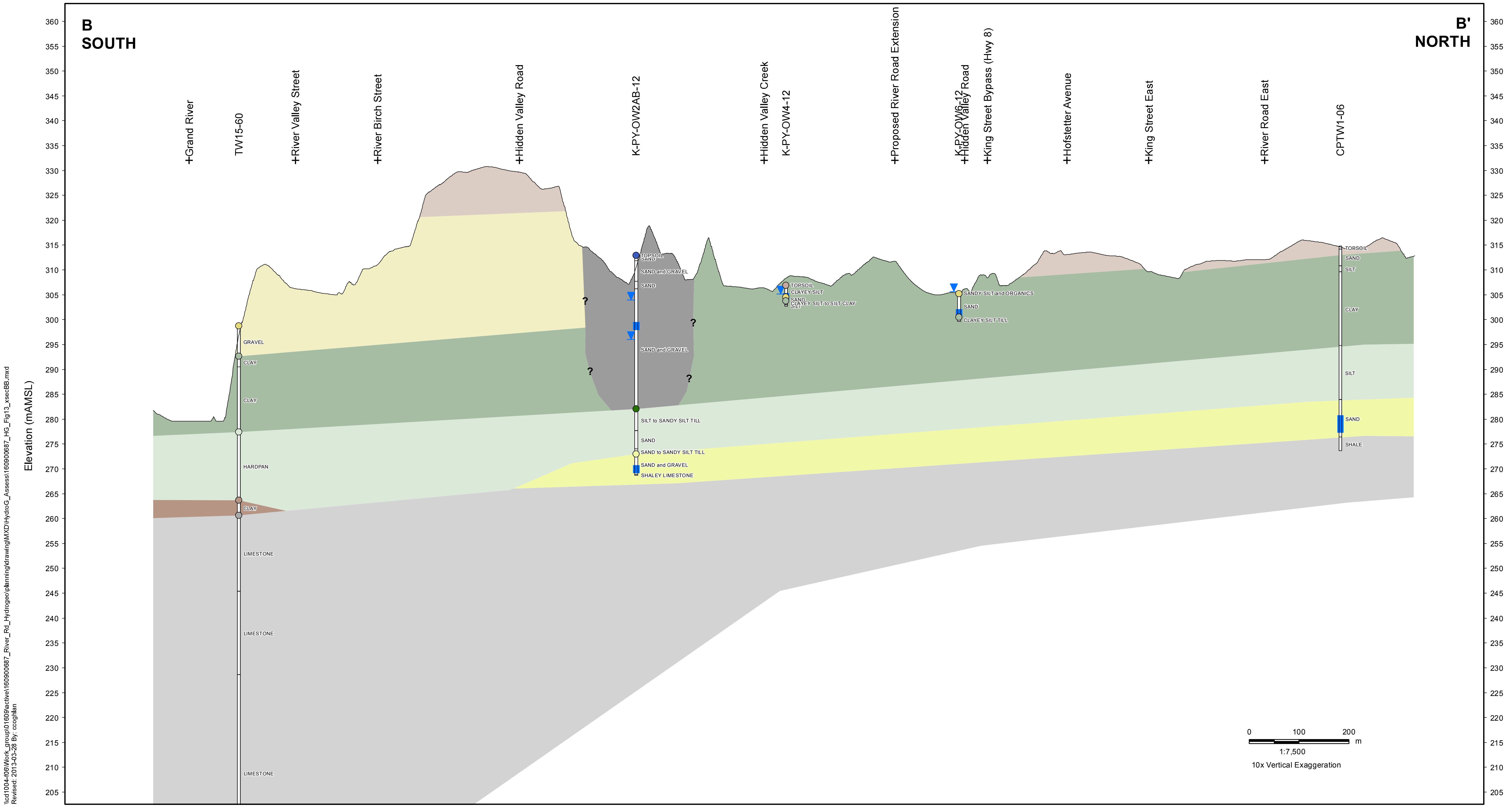
Client/Project
Stage 1 Hydrogeology Study
River Road Extension
King Street to Manitou Drive, Kitchener, Ontario

Figure No.
12

Title
Cross-Section A-A'



March 2013
160900687

Legend

- OW1-12 — Well ID
- Sand — Stratigraphy
- Water Level (July 1, 2012)
- Well Screen
- + Crossing
- O Formation Pick
- Esker
- ATB1 - Upper Maryhill, Port Stanley Till (Aquitard 1)
- AFB1/AFB2 - Upper/Middle Moraine Stratified Sediments & Equivalents (Aquifer 1)
- ATB2 - Middle Maryhill Till and Equivalents (Aquifer 1)
- ATB3 - Lower Maryhill Till and Equivalents (Aquitard 2)
- ATC1/ATC2 - Catfish Creek Till (Aquitard 3)
- AFD1 - Pre-Catfish Sand & Gravel (Aquifer 3)
- ATE1 - Canning Drift Till (Aquitard 4)
- Bedrock - Salina Formation

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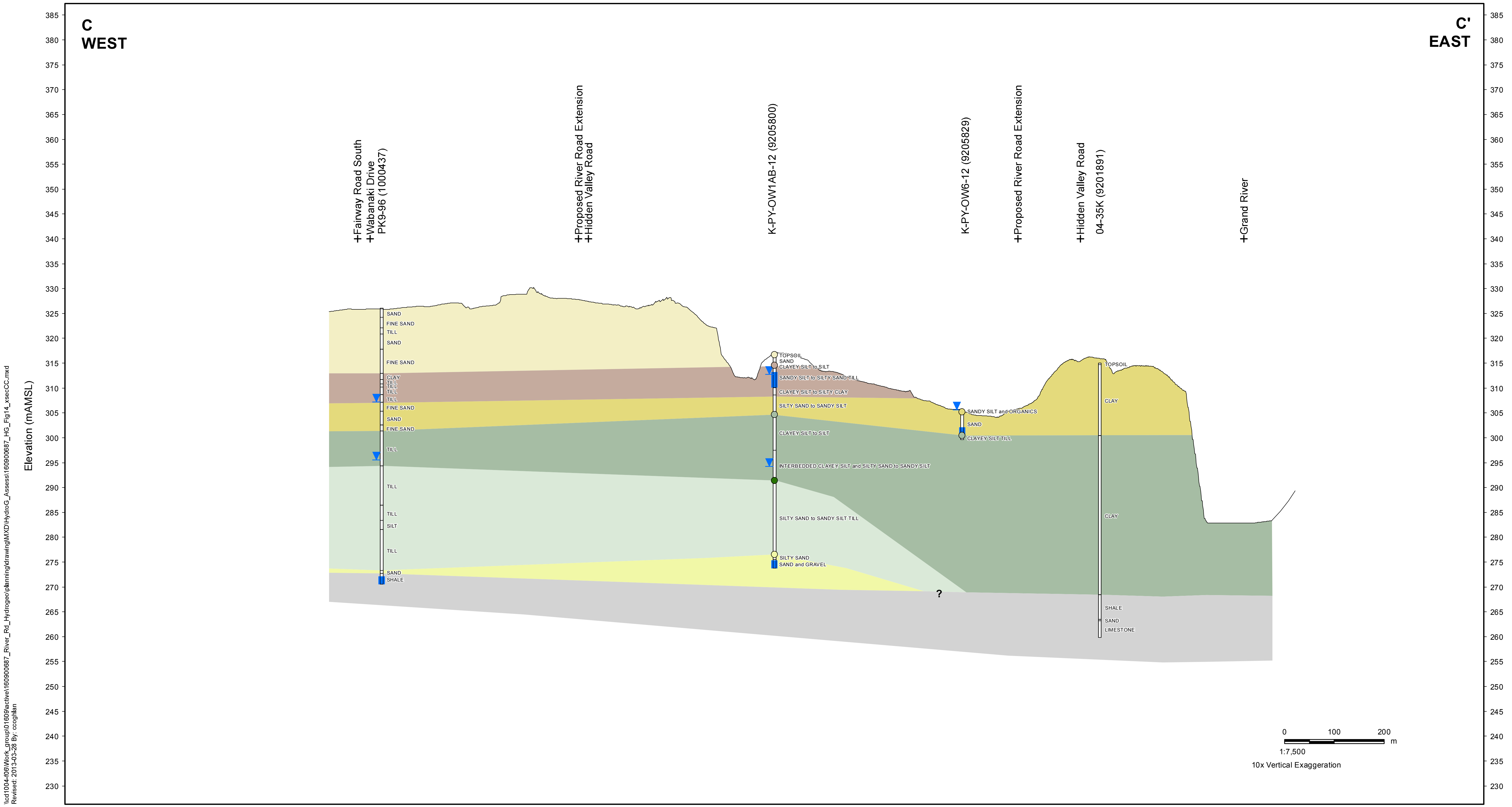
Client/Project

Stage 1 Hydrogeology Study
River Road Extension
King Street to Manitou Drive, Kitchener, Ontario

Figure No.
13

Title

Cross-Section B-B'



March 2013
160900687

Legend

- OW1-12 — Well ID
- Sand — Stratigraphy
- Water Level (July 1, 2012)
- Well Screen
- + Crossing
- O Formation Pick
- Esker
- ATB1 - Upper Maryhill, Port Stanley Till (Aquitard 1)
- AFB1 - Upper Moraine Stratified Sediments and Equivalents (Aquifer 1)
- AFB2 - Middle Moraine Stratified Sediments and Equivalents (Aquifer 1)
- ATB2 - Middle Maryhill Till and Equivalents (Aquifer 1)
- ATB3 - Lower Maryhill Till and Equivalents (Aquitard 2)
- ATC1/ATC2 - Catfish Creek Till (Aquitard 3)
- AFD1 - Pre-Catfish Sand & Gravel (Aquifer 3)
- ATE1 - Canning Drift Till (Aquitard 4)
- Bedrock - Salina Formation

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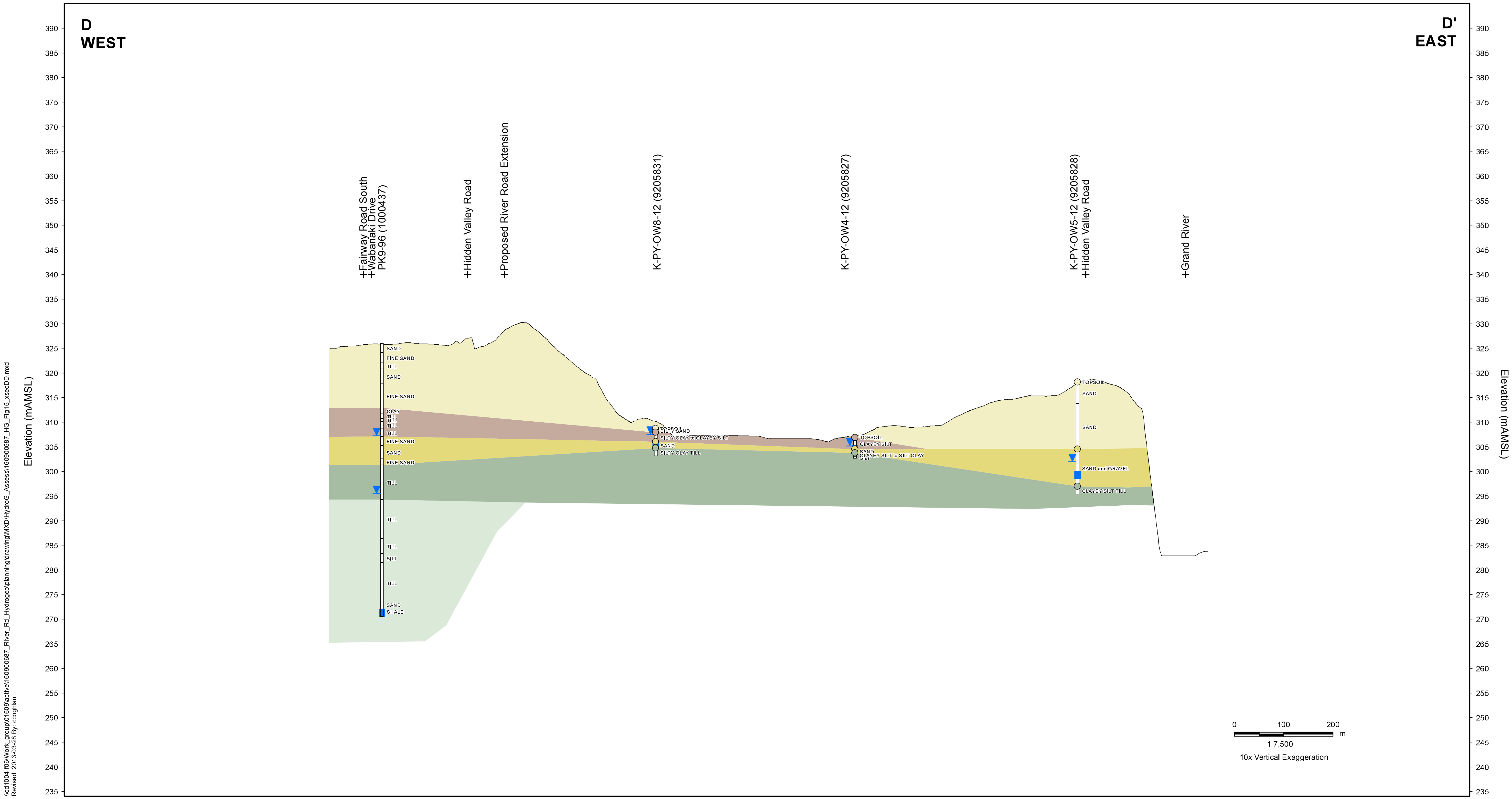
Client/Project

Stage 1 Hydrogeology Study
River Road Extension
King Street to Manitou Drive, Kitchener, Ontario

Figure No.
14

Title
Cross-Section C-C'



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Revised: 2013-03-28 By: ccoghlan

March 2013
160900687

Legend

- Well ID (OW1-12)
- Stratigraphy
- Water Level (July 1, 2012)
- Well Screen
- + Crossing
- O Formation Pick
- Esker
- ATB1 - Upper Maryhill, Port Stanley Till (Aquitard 1)
- AFB1 - Upper Moraine Stratified Sediments and Equivalents (Aquifer 1)
- AFB2 - Middle Moraine Stratified Sediments and Equivalents (Aquifer 1)
- ATB2 - Middle Maryhill Till and Equivalents (Aquifer 1)
- ATB3 - Lower Maryhill Till and Equivalents (Aquitard 2)
- ATC1/ATC2 - Catfish Creek Till (Aquitard 3)
- AFD1 - Pre-Catfish Sand & Gravel (Aquifer 3)
- ATE1 - Canning Drift Till (Aquitard 4)
- Bedrock - Salina Formation

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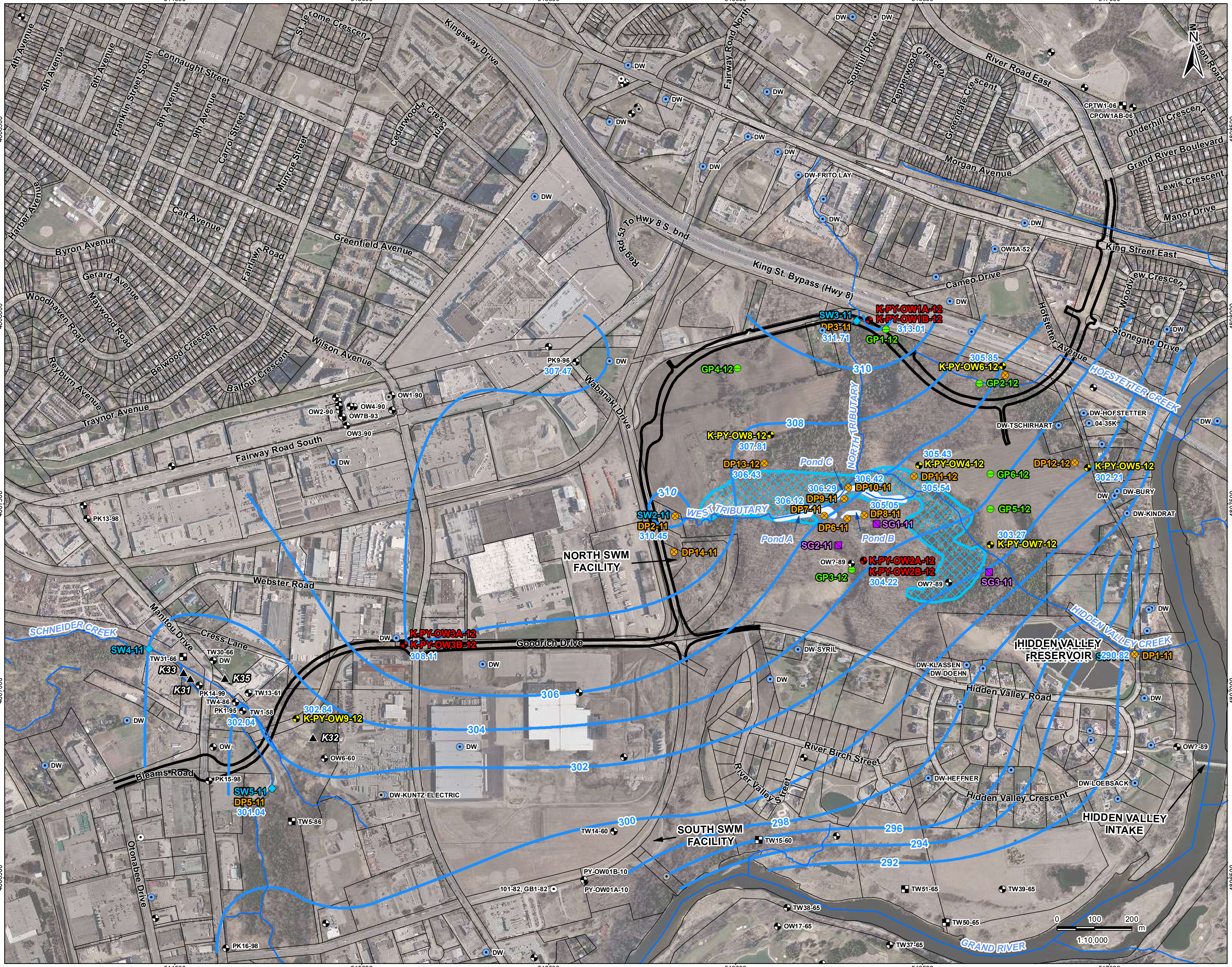
Client/Project

Stage 1 Hydrogeology Study
River Road Extension
King Street to Manitou Drive, Kitchener, Ontario

Figure No.
15

Title
Cross-Section D-D'



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Revised: 2013-03-28 By: ccoghlan

Legend

- Production Well
- Deep Monitoring Well (Stantec, 2012)
- Shallow Monitoring Well (Stantec, 2012)
- Drive-Point Piezometer (Stantec, 2011/2012)
- Guelph Permeameter (Stantec, 2012)
- Surface Water Monitoring Location (Stantec, 2011)
- Staff Gauge (Stantec, 2011)
- Observation Well
- Test Hole
- Water Supply Well
- Unknown Well Type
- Abandoned Well
- Proposed Road Alignment
- 305.00 Groundwater Elevation (mAMSL) (July 1, 2012)
- Groundwater Contour (mAMSL)
- Watercourse
- Ponded Area (Stantec, 2011)
- Vernal Pond (LGL, June 2009)
- Parcel Fabric

Notes

1. Coordinate System: NAD 1983 UTM Zone 17N
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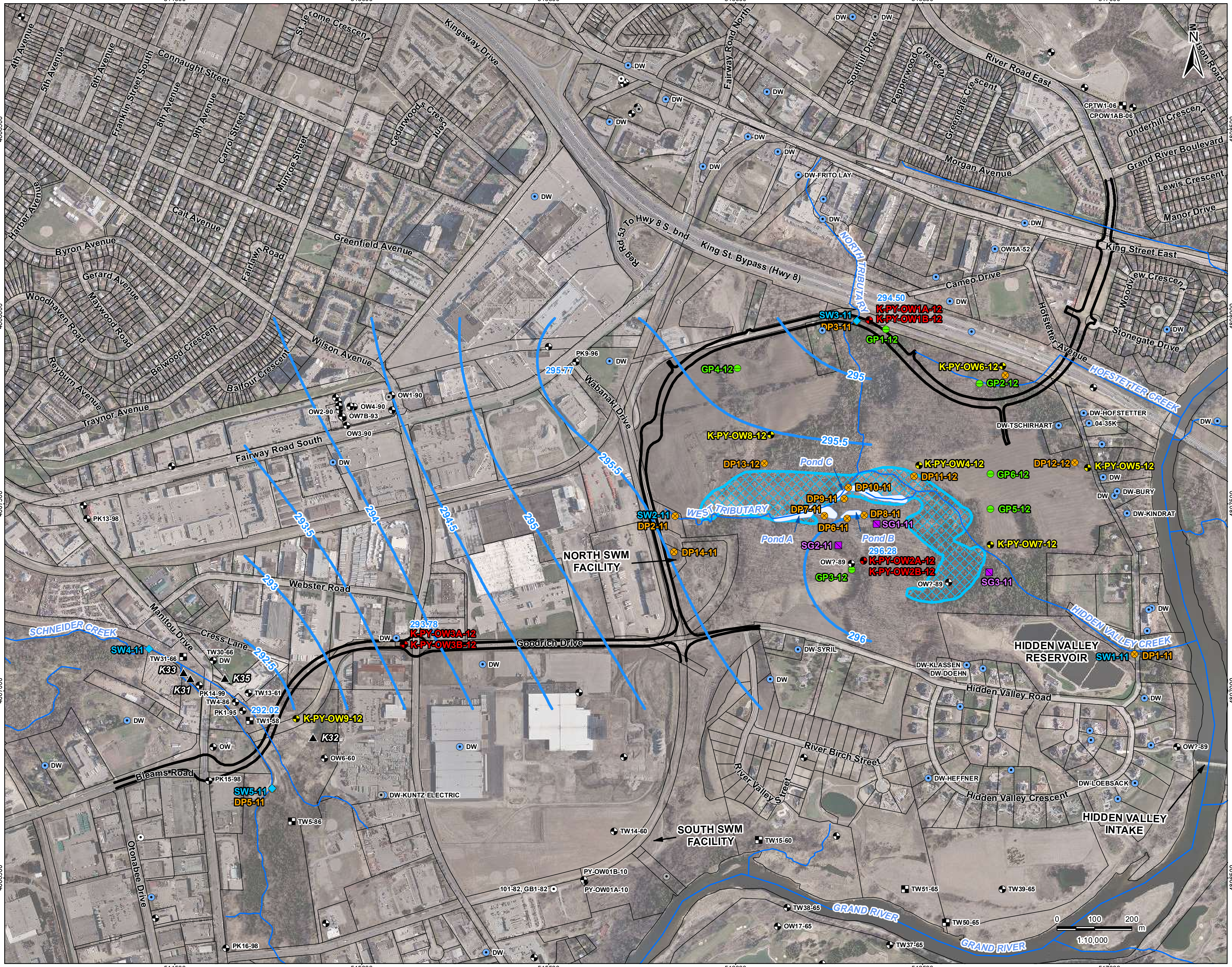
Client/Project
Stage 1 Hydrogeology Study
River Road Extension
King Street to Manitou Drive, Kitchener, Ontario

Figure No.
24

Title
Groundwater Elevation and Interpreted Flow - Aquifer 1 (AFB1/AFB2)



Legend

- Production Well
- Deep Monitoring Well (Stantec, 2012)
- Shallow Monitoring Well (Stantec, 2012)
- Drive-Point Piezometer (Stantec, 2011/2012)
- Guelph Permeameter (Stantec, 2012)
- Surface Water Monitoring Location (Stantec, 2011)
- Staff Gauge (Stantec, 2011)
- Observation Well
- Test Hole
- Water Supply Well
- Unknown Well Type
- Abandoned Well
- Proposed Road Alignment
- 305.00 Groundwater Elevation (mAMSL)
- Groundwater Contour (mAMSL)
- Watercourse
- Ponded Area (Stantec, 2011)
- Vernal Pond (LGL, June 2009)
- Parcel Fabric

Notes

1. Coordinate System: NAD 1983 UTM Zone 17N
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Client/Project
Stage 1 Hydrogeology Study
River Road Extension
King Street to Manitou Drive, Kitchener, Ontario

Figure No.
25

Title
Groundwater Elevation and Interpreted Flow - Aquifer 3 (AFD1)

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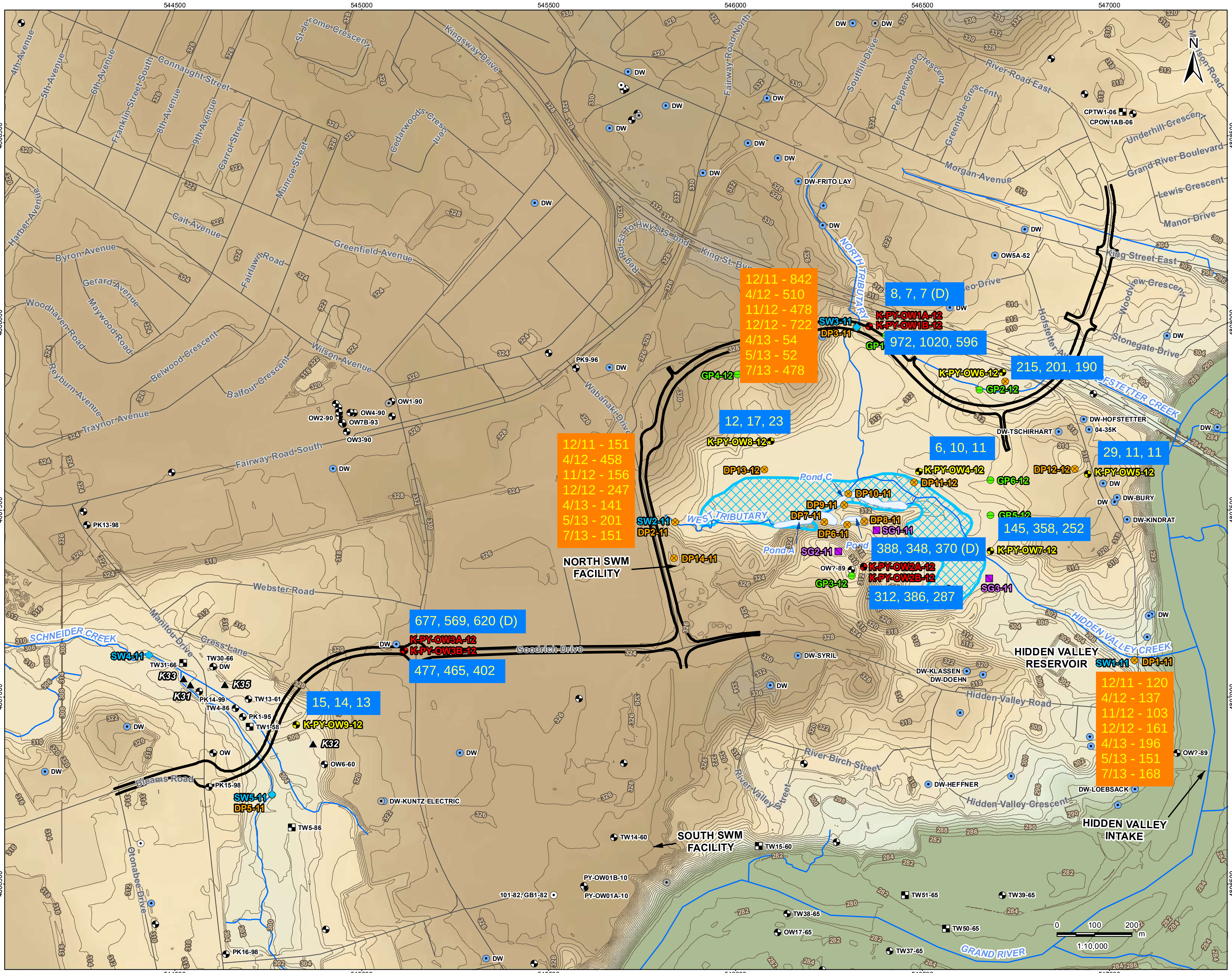
Revised: 2013-03-28 By: ccoghlan

Appendix A2

Groundwater / Surface Water Quality Information (Stantec 2013/2014)



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Revised: 2013-03-28 By: ccoghlan

Legend

- Production Well
- Deep Monitoring Well (Stantec, 2012)
- Shallow Monitoring Well (Stantec, 2012)
- Drive-Point Piezometer (Stantec 2011/2012)
- Guelph Permeameter (Stantec, 2012)
- Surface Water Monitoring Location (Stantec, 2011)
- Staff Gauge (Stantec, 2011)
- Observation Well
- Test Hole
- Water Supply Well
- Unknown Well Type
- Abandoned Well
- Proposed Road Alignment
- Topographic Contour (mAMSL)
- Watercourse
- Ponded Area (Stantec, 2011)
- Vernal Pond (LGL, June 2009)

Ground Surface Elevation (mAMSL)

360
344
328
311
295
278

x, y, z = GW chloride concentrations as sampled Apr. 2012, Nov. 2012, and May 2013

(D) = deep wells, all others are shallow

month/yr - SW chloride concentration (mg/L)

Notes

1. Coordinate System: NAD 1983 UTM Zone 17N
2. Base features produced under license with the Ontario Ministry of Natural Resources © Queen's Printer for Ontario, 2011.
3. Topographic Contours (1 m) derived from the Region of Waterloo Digital Elevation Model © Region of Waterloo, 2003.
4. Parcel fabric © Region of Waterloo, 2009.

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Client/Project
Stage 1 Hydrogeology Study
River Road Extension
King Street to Manitou Drive, Kitchener, Ontario

Figure No.
2

Title
Ground Surface Topography

Table 3
Groundwater Quality Results
2013 Pre-Construction Groundwater and Surface Water Monitoring
Proposed River Road Extension - King Street to Manitou Drive, Kitchener, ON

Sample Location			K-PY-OW1A-12					K-PY-OW1B-12			K-PY-OW2A-12					K-PY-OW2B-12				
Sample Date			26-Apr-12	26-Apr-12	26-Apr-12	7-Nov-12	28-May-13	26-Apr-12	6-Nov-12	28-May-13	26-Apr-12	26-Apr-12	26-Apr-12	7-Nov-12	30-May-13	26-Apr-12	26-Apr-12	26-Apr-12	7-Nov-12	30-May-13
Sample ID			K-PY-MW1A-12	K-PY-MW1A-12	K-PY-MW1A-12 Duplicate	K-PY-MW1A-12	K-PY-OW1A-12	K-PY-MW1B-12	K-PY-MW1B-12	K-PY-OW1B-12	K-PY-MW2A-12	K-PY-MW2A-12	K-PY-MW2A-12	K-PY-MW2A-12	K-PY-OW2A-12	K-PY-MW2B-12	K-PY-MW2B-12	K-PY-MW2B-12	K-PY-MW2B-12	K-PY-OW2B-12
Sampling Company			STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC
Laboratory			EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON
Laboratory Work Order			3203724	3203774	3203724	3210115	3304826	3203774	3210054	3304826	3203724	3203774	3203774	3210115	3304946	3203724	3203774	3203774	3210115	3304946
Laboratory Sample ID			372903	373112	372904	398602	422811	373111	398358	422816	372905	372905	373114	398595	423283	372906	372906	373113	398596	423284
Sample Type	Units	ODWS			Field Duplicate															
Aquifer Unit			AFD1	AFD1	AFD1	AFD1	AFD1	ATB2	ATB2	ATB2	AFD1	AFD1	AFD1	AFD1	AFD1	ATB2/ATB3	ATB2/ATB3	ATB2/ATB3	ATB2/ATB3	ATB2/ATB3
Field Parameters																				
Dissolved oxygen, Field	mg/L	n/v	-	0.4	-	0	1.7	6.4	5.2	7.9	-	0.2	-	0.4	8.5	-	0	-	0.7	0.3
Electrical Conductivity, Field	mS/cm	n/v	-	-	-	-	-	-	-	-	-	-	-	1.650	-84.6	-	-	-	-	-
Oxidation Reduction Potential	mV	n/v	-	-92.3	-	-66.7	-44.2	-	76.1	52.4	-	-	-	-69.0	-	-	-	-	-99.4	-172.7
pH, Field	S.U.	$6.5\text{-}8.5^{E}$	-	7.23	-	7.14	7.34	7.15	7.23	7.53	-	7.35	-	7.34	7.38	-	7.43	-	7.43	7.42
Specific Conductance	mS/cm	n/v	-	1.242	-	1.38	1.325	6.593	3.91	2.530	-	1.731	-	-	1.804	-	1.453	-	1.61	1.431
Temperature, Field	deg C	15^{C}	-	9.95	-	10.1	10.08	8.79	13.1	8.84	-	9.22	-	9.4	9.43	-	9.65	-	9.1	9.57
General Chemistry																				
Alkalinity, Total (as CaCO3)	mg/L	$30\text{-}500^{E}$	-	201	202	196	192	379	387	356 LK	264	-	-	258	251	268	-	-	231	232
Chloride	mg/L	250^{C}	8.43	-	8.49	7.20	6.52	**972^{C}**	**1020^{C}**	**596^{C}**	**388^{C}**	-	-	**348^{C}**	**370^{C}**	**312^{C}**	-	-	**386^{C}**	**287^{C}**
Dissolved Organic Carbon (DOC)	mg/L	5^{C}	**12.7^{C}**	-	1.6	1.3	0.83	2.4	4.3	1.97	3.0	-	-	3.0	1.48	**9.4^{C}**	-	-	4.5	3.71
Hardness (as CaCO3)	mg/L	$80\text{-}100^{E}$	-	**778^{E}**	-	**773^{E}**	**777^{E}**	**616^{E}**	**799^{E}**	**470^{E}**	-	-	**281^{E}**	**334^{E}**	**300^{E}**	-	-	**268^{E}**	**331^{E}**	**207^{E}**
Nitrate (as N)	mg/L	10.0_{d}^{B}	< 0.10	-	< 0.10	< 0.10	< 0.10	1.18	0.84	0.46	< 0.10	-	-	< 0.10	< 0.10	< 0.10	-	-	< 0.10	< 0.10
Nitrite (as N)	mg/L	1.0_{d}^{B}	< 0.015	-	< 0.015	< 0.015	< 0.015	< 0.075	< 0.15	< 0.150 MI	< 0.075	-	-	< 0.15	< 0.150	< 0.075	-	-	< 0.15	< 0.150
pH	S.U.	$6.5\text{-}8.5^{E}$	-	7.77 EST	7.74 EST	7.59 EST	7.79	7.74 EST	7.58 EST	7.75 EST LK	7.88 EST	-	-	7.72 EST	8.10	7.90 EST	-	-	7.65 EST	8.11
Sulfate	mg/L	500_{h}^{C}	**534^{C}**	-	**532^{C}**	**517^{C}**	**552^{C}**	39.0	42.0	33.4	31.3	-	-	18.4	16.5	22.6	-	-	9.6	13.5
Metals																				
Aluminum	mg/L	0.1^{E}	-	< 0.010	-	**0.112^{E}**	< 0.030	< 0.010	< 0.10	< 0.030	-	-	0.022	< 0.010	< 0.030	-	-	< 0.010	< 0.010	< 0.030
Calcium	mg/L	n/v	-	248	-	243	244	160	202	121	-	-	76.6	98.9	82.6	-	-	70.3	98.4	57.7
Iron	mg/L	0.3^{C}	-	**0.515^{C}**	-	**0.420^{C}**	**0.664^{C}**	0.065	***< 0.50***	0.028	-	-	0.073	0.113	0.261	-	-	**0.692^{C}**	**1.99^{C}**	**1.42^{C}**
Magnesium	mg/L	n/v	-	38.6	-	40.3	40.8	52.6	71.5	40.8	-	-	21.7	21.2	22.7	-	-	22.4	20.8	15.3
Manganese	mg/L	0.05^{C}	-	0.050	-	0.0450	0.039	0.046	0.032	0.006	-	-	0.030	0.0493	**0.052^{C}**	-	-	**0.351^{C}**	**0.403^{C}**	**0.28^{C}**
Potassium	mg/L	n/v	-	1.25	-	1.0	1.14	3.42	< 10	2.38	-	-	5.5	3.1	3.72	-	-	2.99	2.4	2.27
Sodium	mg/L	200_{g}^{C} 20_{g}^{D}	-	19	-	12.7	16.7	**533^{CD}**	**660^{CD}**	**341^{CD}**	-	-	**269^{CD}**	**249^{CD}**	**239^{CD}**	-	-	**212^{CD}**	**239^{CD}**	**200^{D}**

See notes on last page.

Table 3
Groundwater Quality Results
2013 Pre-Construction Groundwater and Surface Water Monitoring
Proposed River Road Extension - King Street to Manitou Drive, Kitchener, ON

Sample Location			K-PY-OW3A-12					K-PY-OW3B-12				
Sample Date			26-Apr-12	26-Apr-12	26-Apr-12	7-Nov-12	28-May-13	26-Apr-12	26-Apr-12	26-Apr-12	7-Nov-12	28-May-13
Sample ID			K-PY-MW3A-12	K-PY-MW3A-12	K-PY-MW3A-12	K-PY-MW3A-12	K-PY-OW3A-12	K-PY-MW3B-12	K-PY-MW3B-12	K-PY-MW3B-12	K-PY-MW3B-12	K-PY-OW3B-12
Sampling Company			STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC
Laboratory			EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON
Laboratory Work Order			3203724	3203774	3203774	3210115	3304826	3203724	3203774	3203774	3210115	3304826
Laboratory Sample ID			372901	372901	373116	398597	422817	372902	372902	373115	398598	422818
Sample Type	Units	ODWS										
Aquifer Unit			AFD1	AFD1	AFD1	AFD1	AFD1	AFB1/AFB2	AFB1/AFB2	AFB1/AFB2	AFB1/AFB2	AFB1/AFB2
Field Parameters												
Dissolved oxygen, Field	mg/L	n/v	-	7.8	-	7.8	1.7	-	6.7	-	6.94	1.5
Electrical Conductivity, Field	mS/cm	n/v	-	-	-	-	-	-	-	-	-	-
Oxidation Reduction Potential	mV	n/v	-	71.4	-	27.6	2.3	-	-	-	-17.9	69.1
pH, Field	S.U.	$6.5\text{-}8.5^{E}$	-	7.22	-	7.11	7.29	-	7.24	-	7.11	7.25
Specific Conductance	mS/cm	n/v	-	2.774	-	2.62	2.799	-	2.083	-	2.08	2.023
Temperature, Field	deg C	15^{C}	-	12.28	-	12.6	12.48	-	11.99	-	11.7	12.33
General Chemistry												
Alkalinity, Total (as CaCO3)	mg/L	$30\text{-}500^{E}$	342	-	-	335	335	317	-	-	316	309
Chloride	mg/L	250^{C}	**677^{C}**	-	-	**569^{C}**	**620^{C}**	**477^{C}**	-	-	**465^{C}**	**402^{C}**
Dissolved Organic Carbon (DOC)	mg/L	5^{C}	2.7	-	-	1.8	0.82	4.1	-	-	2.1	0.84
Hardness (as CaCO3)	mg/L	$80\text{-}100^{E}$	-	-	**562^{E}**	**550^{E}**	**549^{E}**	-	-	**471^{E}**	**507^{E}**	**455^{E}**
Nitrate (as N)	mg/L	10.0_{d}^{B}	4.71	-	-	4.79	5.18	4.39	-	-	4.50	4.44
Nitrite (as N)	mg/L	1.0_{d}^{B}	< 0.075	-	-	< 0.15	< 0.150 MI	< 0.075	-	-	< 0.15	< 0.150 MI
pH	S.U.	$6.5\text{-}8.5^{E}$	7.73 EST	-	-	7.51 EST	7.80	7.73 EST	-	-	7.56 EST	7.79
Sulfate	mg/L	500_{h}^{C}	69.6	-	-	69.3	72.6	35.2	-	-	32.2	32.0
Metals												
Aluminum	mg/L	0.1^{E}	-	-	< 0.010	< 0.10	< 0.030	-	-	< 0.010	< 0.010	< 0.030
Calcium	mg/L	n/v	-	-	150	145	147	-	-	131	143	124
Iron	mg/L	0.3^{C}	-	-	0.056	***< 0.50***	0.032	-	-	0.048	0.103	0.030
Magnesium	mg/L	n/v	-	-	45.5	45.6	44.1	-	-	34.9	36.3	35.4
Manganese	mg/L	0.05^{C}	-	-	**0.122^{C}**	0.016	< 0.003	-	-	0.008	0.0087	< 0.003
Potassium	mg/L	n/v	-	-	3.53	< 10	2.33	-	-	1.95	1.7	1.76
Sodium	mg/L	$200_{g}^{C}\ 20_{g}^{D}$	-	-	**405^{CD}**	**364^{CD}**	**360^{CD}**	-	-	**274^{CD}**	**271^{CD}**	**227^{CD}**

Sample Location	K-PY-OW4-12			K-PY-OW5-12			K-PY-OW6-12			
Sample Date	27-Apr-12	6-Nov-12	28-May-13	27-Apr-12	6-Nov-12	28-May-13	27-Apr-12	6-Nov-12	6-Nov-12	28-May-13
Sample ID	K-PY-MW4-12	K-PY-MW4-12	K-PY-OW4-12	K-PY-MW5-12	K-PY-MW5-12	K-PY-OW5-12	K-PY-MW6-12	K-PY-MW6-12	K-PY-MW6-12 DUPLICATE	K-PY-OW6-12
Sampling Company	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC
Laboratory	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON
Laboratory Work Order	3203812	3210054	3304826	3203812	3210054	3304826	3203812	3210054	3210054	3304826
Laboratory Sample ID	373377	398359	422814	373380	398360	422813	373379	398362	398364	422812
Sample Type									Field Duplicate	
Aquifer Unit	AFB2	AFB2	AFB2	AFB2	AFB2	AFB2	AFB2	AFB2	AFB2	AFB2
Field Parameters										
Dissolved oxygen, Field	8.8	6.9	5.5	3.1	2.0	3.9	1.6	1.4	-	2.1
Electrical Conductivity, Field	-	-	-	-	-	-	-	-	-	-
Oxidation Reduction Potential	-	76.3	94.0	-	53.8	93.1	-	54.8	-	46.8
pH, Field	7.36	7.26	7.55	7.64	7.64	7.72	7.16	7.13	-	7.41
Specific Conductance	0.541	0.423	0.592	0.581	0.578	0.548	1.412	1.46	-	1.482
Temperature, Field	8.21	12.5	9.47	9.03	9.3	9.42	8.89	13.8	-	9.28
General Chemistry										
Alkalinity, Total (as CaCO3)	292	310	275 LK	238	269	246 LK	352	345	334	337 LK
Chloride	6.34	10.0	11.4	28.5	11.0	10.6	215	201	200	190
Dissolved Organic Carbon (DOC)	3.1	2.8	2.57	2.5	1.2	3.02	2.8	1.3	< 1.0	1.57
Hardness (as CaCO3)	**312^{E}**	**316^{E}**	**334^{E}**	**306^{E}**	**288^{E}**	**301^{E}**	**589^{E}**	**508^{E}**	**532^{E}**	**568^{E}**
Nitrate (as N)	0.99	0.52	4.48	3.77	4.01	5.32	3.31	1.82	1.86	2.80
Nitrite (as N)	< 0.015	< 0.015	< 0.015	0.047	< 0.015	< 0.015	< 0.015	< 0.15	< 0.15	< 0.150
pH	7.76 EST	7.76 EST	7.81 EST LK	7.95 EST	7.95 EST	7.95 EST LK	7.64 EST	7.75 EST	7.82 EST	7.53 EST LK
Sulfate	13.8	12.7	10.6	31.8	18.5	13.2	94.1	75.6	73.4	102
Metals										
Aluminum	0.017	< 0.010	< 0.030	0.030	< 0.010	< 0.030	< 0.010	< 0.010	< 0.010	< 0.030
Calcium	80.3	80.2	85.9	67.8	69.8	76.3	159	129	139	144
Iron	0.038	< 0.050	0.024	0.043	< 0.050	0.024	0.052	< 0.050	< 0.050	0.032
Magnesium	27.1	28.2	28.9	33.3	27.6	26.9	46.5	45.2	44.8	50.5
Manganese	**0.054^{C}**	0.0012	< 0.003	**0.236^{C}**	0.0472	0.021	**0.087^{C}**	0.0019	0.0020	0.007
Potassium	0.355	< 1.0	0.296	2.55	1.3	1.14	1.96	1.6	1.8	1.91
Sodium	6.66	4.91	3.94	11.7	6.38	5.61	**96.5^{D}**	**92.2^{D}**	**91.5^{D}**	**93.5^{D}**

See notes on last page.

Table 3
Groundwater Quality Results
2013 Pre-Construction Groundwater and Surface Water Monitoring
Proposed River Road Extension - King Street to Manitou Drive, Kitchener, ON

Sample Location			K-PY-OW7-12			K-PY-OW8-12			K-PY-OW9-12			PK1A-95		PK1B-95			PK1C-95		PK1D-95	
Sample Date			27-Apr-12	6-Nov-12	28-May-13	27-Apr-12	6-Nov-12	30-May-13	27-Apr-12	8-Nov-12	30-May-13	7-Nov-12	30-May-13	7-Nov-12	30-May-13	30-May-13	13-Nov-12	30-May-13	7-Nov-12	30-May-13
Sample ID			K-PY-MW7-12	K-PY-MW7-12	K-PY-OW7-12	K-PY-MW8-12	K-PY-MW8-12	K-PY-OW8-12	K-PY-MW9-12	K-PY-MW9-12	K-PY-OW9-12	PK1A-95	PK1A-95	PK1B-95	PK1B-95	PK1B-95 (DUP)	PK1C-95	PK1C-95	PK1D-95	PK1D-95
Sampling Company			STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC
Laboratory			EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON
Laboratory Work Order			3203812	3210054	3304826	3203812	3210054	3304946	3203812	3210115	3304946	3210115	3304946	3210115	3304946	3304946	3210239	3304946	3210115	3304946
Laboratory Sample ID			373381	398361	422815	373378	398363	423287	373382	398603	423278	398599	423279	398600	423280	423288	399114	423281	398601	423282
Sample Type	Units	ODWS														Field Duplicate				
Aquifer Unit			AFB2	AFB2	AFB2	AFB2	AFB2	AFB2	ATB3	ATB3	ATB3	Bedrock	Bedrock	AFD1	AFD1	AFD1	ATB3	ATB3	AFB2	AFB2
Field Parameters																				
Dissolved oxygen, Field	mg/L	n/v	1.1	0.5	5.6	8.4	6.6	8.6	3.9	3.8	5.5	0	0.4	1.5	2.1	-	6.04	0.8	0.5	1.7
Electrical Conductivity, Field	mS/cm	n/v	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxidation Reduction Potential	mV	n/v	-	-122.3	-99.4	-	54.1	60.5	-	199.6	82.0	3.3	39.7	58.8	99.7	-	29.4	14.6	-76.9	-43.9
pH, Field	S.U.	6.5-8.5[E]	7.74	7.40	7.72	7.39	7.41	7.49	7.58	6.95	7.53	7.07	7.29	7.04	7.22	-	7.91	8.22	6.83	7.07
Specific Conductance	mS/cm	n/v	0.967	1.71	1.392	0.547	0.638	0.672	0.529	0.512	0.387	1.43	1.645	2.60	2.589	-	0.371	0.470	1.73	1.029
Temperature, Field	deg C	15[C]	9.20	9.5	9.34	7.56	11.1	9.70	10.31	11.8	10.45	10.6	10.82	10.8	11.29	-	11.6	10.84	12.7	8.88
General Chemistry																				
Alkalinity, Total (as CaCO3)	mg/L	30-500[E]	277	267	280 LK	261	280	246	206	218	228	254	271	286	270	273	154	155	**506**[E]	459
Chloride	mg/L	250[C]	145	**358**[C]	**252**[C]	11.5	16.9	23.4	15.4	13.7	13.3	**256**[C]	**313**[C]	**491**[C]	**426**[C]	**430**[C]	5.22	4.05	246	58.5
Dissolved Organic Carbon (DOC)	mg/L	5[C]	**5.5**[C]	**7.3**[C]	4.32	2.6	2.2	1.39	4.1	3.5	**8.04**[C]	1.4	0.67	1.1	0.73	0.68	-	1.59	**9.2**[C]	4.97
Hardness (as CaCO3)	mg/L	80-100[E]	**233**[E]	**338**[E]	**265**[E]	**290**[E]	**295**[E]	**346**[E]	**244**[E]	**237**[E]	**236**[E]	**522**[E]	**498**[E]	**910**[E]	**840**[E]	**837**[E]	-	**79.0**[E]	**600**[E]	**464**[E]
Nitrate (as N)	mg/L	10.0_d[B]	< 0.10	< 0.10	< 0.10	5.23	3.52	**10.1**[B]	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	3.11	1.86	1.87	0.10	0.48	< 0.10	< 0.10
Nitrite (as N)	mg/L	1.0_d[B]	< 0.015	< 0.15	< 0.150 MI	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.15	< 0.150	< 0.15	< 0.150	< 0.150	< 0.015	< 0.015	< 0.15	< 0.015
pH	S.U.	6.5-8.5[E]	8.37 EST	7.94 EST	7.96 EST LK	7.73 EST	7.89 EST	7.82	8.27 EST	7.94 EST	8.23	7.68 EST	7.93	7.54 EST	7.83	7.89	8.23 EST	8.36	7.29 EST	7.80
Sulfate	mg/L	500_h[C]	34.0	8.9	18.0	14.5	18.7	14.3	67.7	39.8	40.0	75.0	79.7	355	395	400	60.3	73.5	78.5	15.2
Metals																				
Aluminum	mg/L	0.1[E]	0.034	< 0.010	< 0.030	< 0.010	< 0.010	< 0.030	< 0.010	< 0.010	< 0.030	< 0.010	< 0.030	< 0.010	< 0.030	< 0.030	-	< 0.030	< 0.010	< 0.030
Calcium	mg/L	n/v	46.3	76.4	62.9	87.1	82.7	97.5	59.4	54.4	53.1	142	125	278	247	246	-	19.6	179	127
Iron	mg/L	0.3[C]	0.063	**1.21**[C]	**1.06**[C]	0.028	< 0.050	0.027	0.036	< 0.050	0.026	0.076	0.035	0.080	0.036	0.037	-	0.017	**5.52**[C]	**1.91**[C]
Magnesium	mg/L	n/v	28.5	35.7	26.3	17.5	21.6	24.9	23.3	24.5	25.1	40.7	45.1	52.3	54.1	54.0	-	7.28	37.2	35.7
Manganese	mg/L	0.05[C]	0.050	**0.0823**[C]	**0.060**[C]	**0.098**[C]	**0.103**[C]	0.049	**0.057**[C]	**0.0686**[C]	0.017	**0.0836**[C]	**0.080**[C]	< 0.0010	-	< 0.003	-	0.009	**0.448**[C]	**0.268**[C]
Potassium	mg/L	n/v	4.20	2.6	2.41	1.35	1.6	1.68	2.77	1.7	1.72	1.7	2.19	2.6	2.90	28.7	-	1.06	4.6	1.91
Sodium	mg/L	200_g[C] 20_g[D]	**129**[D]	**227**[CD]	**178**[D]	13.6	12.7	13.9	**30.9**[D]	**31.6**[D]	**31.3**[D]	**96.5**[D]	**120**[D]	**254**[CD]	**224**[CD]	**224**[CD]	-	**74**[D]	**192**[D]	**51.2**[D]

See notes on last page.

Table 3
Groundwater Quality Results
2013 Pre-Construction Groundwater and Surface Water Monitoring
Proposed River Road Extension - King Street to Manitou Drive, Kitchener, ON

Sample Location			PK9A-96		PK9B-96	
Sample Date			**8-Nov-12**	**30-May-13**	**8-Nov-12**	**30-May-13**
Sample ID			**PK9A-96**	**PK9A-96**	**PK9B-96**	**PK9B-96**
Sampling Company			**STANTEC**	**STANTEC**	**STANTEC**	**STANTEC**
Laboratory			**EELS-WON**	**EELS-WON**	**EELS-WON**	**EELS-WON**
Laboratory Work Order			**3210174**	**3304946**	**3210174**	**3304946**
Laboratory Sample ID			**398798**	**423285**	**398799**	**423286**
Sample Type	**Units**	**ODWS**				
Aquifer Unit			**AFD1/Bedrock**	**AFD1/Bedrock**	**AFB1/AFB2**	**AFB1/AFB2**
Field Parameters						
Dissolved oxygen, Field	mg/L	n/v	0	0.6	3.4	3.9
Electrical Conductivity, Field	mS/cm	n/v	-	-	-	-
Oxidation Reduction Potential	mV	n/v	-132.6	-140.3	-46.0	-63.5
pH, Field	S.U.	6.5-8.5^E	7.41	7.61	7.32	7.60
Specific Conductance	mS/cm	n/v	0.680	0.636	1.03	1.070
Temperature, Field	deg C	15^C	10.1	11.44	9.6	10.01
General Chemistry						
Alkalinity, Total (as CaCO3)	mg/L	30-500^E	204	206	278	275
Chloride	mg/L	250^C	4.78	4.30	150	147
Dissolved Organic Carbon (DOC)	mg/L	5^C	1.2	1.08	1.5	2.22
Hardness (as CaCO3)	mg/L	80-100^E	**375^E**	**360^E**	**395^E**	**398^E**
Nitrate (as N)	mg/L	10.0$_d^B$	< 0.10	< 0.10	1.26	1.26
Nitrite (as N)	mg/L	1.0$_d^B$	< 0.015	< 0.015	< 0.015	< 0.150
pH	S.U.	6.5-8.5^E	7.98 EST	8.14	7.88 EST	8.04
Sulfate	mg/L	500$_h^C$	167	145	38.0	38.2
Metals						
Aluminum	mg/L	0.1^E	< 0.010	< 0.030	< 0.010	< 0.030
Calcium	mg/L	n/v	96.0	92.4	98.4	98.2
Iron	mg/L	0.3^C	**0.656^C**	**0.637^C**	< 0.050	0.035
Magnesium	mg/L	n/v	32.8	31.4	36.3	37.1
Manganese	mg/L	0.05^C	0.0452	0.050	0.0011	< 0.003
Potassium	mg/L	n/v	< 1.0	1.04	1.6	1.80
Sodium	mg/L	200$_g^C$ 20$_g^D$	11.4	13.1	**80.2^D**	**72.1^D**

Notes:

ODWS	Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines, June 2003, Revised June 2006
A	ODWS Table 2 - Chemical Standards, Interim Maximum Acceptable Concentration
B	ODWS Table 2 - Chemical Standards, Maximum Acceptable Concentration
C	ODWS Table 4 - Chemical/Physical Objectives and Guidelines, Aesthetic Objectives
D	ODWS Table 4 - Medical Officer of Health Reporting Limit
E	ODWS Table 4 - Chemical/Physical Objectives and Guidelines, Operational Guidelines
6.5^A	Concentration exceeds the indicated standard.
15.2	Concentration was detected but did not exceed applicable standards.
< 0.50	Laboratory estimated quantitation limit exceeded standard.
< 0.03	The analyte was not detected above the laboratory estimated quantitation limit.
n/v	No standard/guideline value.
-	Parameter not analyzed / not available.
d	Where both nitrate and nitrite are present, the total of the two should not exceed 10 mg/L (as nitrogen).
g	The aesthetic objective for sodium in drinking water is 200 mg/L. The local Medical Officer of Health should be notified when the sodium concentration exceeds 20 mg/L so that this information may be communicated to local physicians for their use with patients on sodium restricted diets.
h	When sulfate levels exceed 500 mg/L, water may have a laxative effect on some people.
EST	Estimated Value
LK	Sample filtered for pH and Alkalinity - filtrate analyzed.
MI	Detection limit was raised due to matrix interferences.

Table 5
Surface Water Quality Results
2013 Pre-Construction Groundwater and Surface Water Monitoring
Proposed River Road Extension - King Street to Manitou Drive, Kitchener, ON

Sample Location				POND A		POND B			POND C	
Sample Date				29-May-13	30-Jul-13	29-May-13	29-May-13	30-Jul-13	29-May-13	30-Jul-13
Sample ID				POND A	POND A	POND B	POND B DUP	POND B	POND C	POND C
Sampling Company				STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC
Laboratory				EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON
Laboratory Work Order				3304890	3306987	3304890	3304890	3306987	3304890	3306987
Laboratory Sample ID				423072	430869	423070	423073	430868	423071	430867
Sample Type	Units	PWQO	CCME				Field Duplicate			
Field Parameters										
Dissolved oxygen, Field	mg/L	$_{s9}^{A}$	n/v	5.5	7.9	7.2	-	3.5	5.6	15.0
Oxidation Reduction Potential	mV	n/v	n/v	331.1	145.0	278.4	-	243.5	330.0	97.3
pH, Field	S.U.	$6.5\text{-}8.5^{A}$	n/v	8.0	7.70	7.90	-	8.15	7.83	9.16
Specific Conductance	mS/cm	n/v	n/v	0.468	0.361	0.677	-	0.347	0.550	0.340
Temperature, Field	deg C	30_{s6}^{A}	n/v	17.61	18.5	14.75	-	17.8	17.16	21.4
General Chemistry										
Alkalinity, Total (as CaCO3)	mg/L	$_{s16}^{A}$	n/v	59.9 LK	90.7	80.5 LK	80.6 LK	93.3	81.8 LK	99.0
Chloride	mg/L	n/v	120^{D} 640^{E}	88.8	57.5	80.2	83.1	55.2	**121^{D}**	52.7
Dissolved Organic Carbon (DOC)	mg/L	n/v	n/v	5.39	7.01	6.39	6.44	6.76	5.91	7.11
Hardness (as CaCO3)	mg/L	n/v	n/v	73.0	101	97.0	96.0	105	89.0	111
Nitrate (as N)	mg/L	n/v	2.94^{D} 550^{E}	0.25	< 0.10	0.19	0.20	0.51	0.18	< 0.10
Nitrite (as N)	mg/L	n/v	0.06^{D}	< 0.015	< 0.015	< 0.015	< 0.015	< 0.0150	***< 0.150 MI***	< 0.015
pH	S.U.	$6.5\text{-}8.5^{A}$	$6.5\text{-}9.0^{D}$	7.83 EST LK	7.87	7.93 EST LK	7.94 EST LK	7.57	7.94 EST LK	**8.83^{AD}**
Sulfate	mg/L	n/v	n/v	5.0	5.7	5.4	5.4	4.9	5.6	3.2
Metals										
Aluminum	mg/L	0.075^{C}	$0.005/0.1_{VAR1}^{D}$	**0.631^{CD}**	0.073	**0.546^{CD}**	**0.544^{CD}**	0.042	**0.645^{CD}**	0.056
Calcium	mg/L	n/v	n/v	23.6	32.9	30.1	29.8	34	28.9	35.5
Iron	mg/L	0.3^{A}	0.3^{D}	**0.879^{AD}**	**0.638^{AD}**	**0.914^{AD}**	**0.924^{AD}**	**0.448^{AD}**	**0.968^{AD}**	**0.448^{AD}**
Magnesium	mg/L	n/v	n/v	3.39	4.66	5.29	5.25	4.93	4.10	5.45
Manganese	mg/L	n/v	n/v	0.064	0.050	0.078	0.078	0.073	0.082	0.068
Potassium	mg/L	n/v	n/v	1.45	1.37	1.48	1.48	1.42	1.69	0.834
Sodium	mg/L	n/v	n/v	56.2	36.0	53.6	53.8	36.0	73.2	34.7

Sample Location	SW1A-11								SW1B-11				
Sample Date	14-Dec-11	26-Apr-12	5-Nov-12	12-Dec-12	10-Apr-13	10-Apr-13	29-May-13	30-Jul-13	14-Dec-11	26-Apr-12	12-Dec-12	29-May-13	30-Jul-13
Sample ID	SW1A-11	SW1A-11	SW1-11	SW1A-11	SW1-11	SW9-11	SW1A-11	SW1A	SW1B-11	SW1B-11	SW1B-11	SW1B-11	SW1B
Sampling Company	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC
Laboratory	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON
Laboratory Work Order	3111272	3203775	3210010	3211178	3303189	3303189	3304890	3306987	3111272	3203775	3211178	3304890	3306987
Laboratory Sample ID	356863	373121	398151	402615	416601	416602	423068	430860	356864	373122	402616	423069	430861
Sample Type						Field Duplicate							
Field Parameters													
Dissolved oxygen, Field	8.4	7.4	8.7	12.4	10.5	-	8.8	8.2	10.7	-	12.6	8.8	8.0
Oxidation Reduction Potential	-	-	129.7	60.3	-	-	224.8	101	-	-	42.8	178.2	100.4
pH, Field	7.74	7.63	7.96	7.87	9.06	-	7.89	7.54	7.87	7.61	7.96	8.09	8.11
Specific Conductance	0.888	0.918	0.80	0.876	0.880	-	0.821	0.850	0.768	0.918	0.858	0.803	0.85
Temperature, Field	9.49	9.70	7.8	3.12	6.5	-	14.87	16.2	3.60	9.67	1.88	15.83	17.2
General Chemistry													
Alkalinity, Total (as CaCO3)	234	261	176	169	136 LK	130 LK	160 LK	195	206	262	161	154 LK	191
Chloride	120	**137^{D}**	103	**161^{D}**	**194^{D}**	**197^{D}**	**151^{D}**	**168^{D}**	107	**134^{D}**	**158^{D}**	**138^{D}**	**170^{D}**
Dissolved Organic Carbon (DOC)	2.53	2.6	3.1	5.2	4.61	4.63	7.31	6.53	3.53	2.8	5.8	7.98	8.71
Hardness (as CaCO3)	260	283	272	196	157	142	182	225	234	283	185	175	214
Nitrate (as N)	0.72	0.83	< 0.10	< 0.10	0.29	0.18	0.20	0.18	0.16	0.80	< 0.10	< 0.10	< 0.10
Nitrite (as N)	***< 0.075 MI***	< 0.015	< 0.015	< 0.015	***< 0.075 MI***	***< 0.075 MI***	***< 0.150 MI***	***< 0.075 BQ***	< 0.015	< 0.015	< 0.015	***< 0.150 BQ***	***< 0.075 BQ***
pH	7.77 EST	8.11 EST	7.95 EST	8.15 EST	8.04 EST LK	8.04 EST LK	8.24 EST LK	8.14	7.86 EST	8.09 EST	8.18 EST	8.26 EST LK	8.19
Sulfate	14.7	14.1	10.2	10.3	13.0	12.4	6.3	6.5	11.7	14.0	9.4	5.0	5.4
Metals													
Aluminum	0.013	< 0.010	0.011	0.022	**0.268^{CD}**	**0.350^{CD}**	**0.215^{CD}**	**0.096^{CD}**	0.030	< 0.010	0.026	**0.223^{CD}**	**0.089^{C}**
Calcium	73.2	78.0	77.1	60.5	45.4	41.4	52.3	62.6	67.3	78.2	57.8	50.6	59.5
Iron	0.168	0.072	< 0.050	0.116	**0.571^{AD}**	**0.728^{AD}**	**0.661^{AD}**	**0.449^{AD}**	0.289	0.062	0.142	**0.700^{AD}**	**0.489^{AD}**
Magnesium	18.7	21.4	19.2	10.8	10.5	9.28	12.5	16.8	16.1	21.4	9.93	11.8	15.9
Manganese	0.045	0.024	0.0183	0.0256	0.082	0.089	0.066	0.067	0.078	0.024	0.0286	0.069	0.079
Potassium	1.83	2.04	2.1	1.4	1.76	1.66	1.73	1.95	1.31	2.04	1.3	1.68	1.87
Sodium	75.5	91.7	96.2	92.9	119	118	96.9	100	68.2	91.1	92.3	100	101

See notes on last page.

Table 5
Surface Water Quality Results
2013 Pre-Construction Groundwater and Surface Water Monitoring
Proposed River Road Extension - King Street to Manitou Drive, Kitchener, ON

Sample Location				SW2-11							
Sample Date				14-Dec-11	26-Apr-12	5-Nov-12	12-Dec-12	12-Dec-12	10-Apr-13	29-May-13	30-Jul-13
Sample ID				SW2-11	SW2-11	SW2-11	SW2-11	SW2-Dup	SW2-11	SW2-11	SW2
Sampling Company				STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC
Laboratory				EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON
Laboratory Work Order				3111272	3203775	3210010	3211178	3211178	3303189	3304890	3306987
Laboratory Sample ID				356861	373119	398152	402619	402620	416595	423062	430863
Sample Type	Units	PWQO	CCME					Field Duplicate			
Field Parameters											
Dissolved oxygen, Field	mg/L	$_{s9}$[A]	n/v	9.5	11.5	11.2	11.5	-	9.6	8.5	9.5
Oxidation Reduction Potential	mV	n/v	n/v	-	-	134.4	-50.5	-	-	169.5	-58.3
pH, Field	S.U.	6.5-8.5[A]	n/v	7.58	7.89	8.00	7.92	-	8.95	8.14	7.89
Specific Conductance	mS/cm	n/v	n/v	1.035	1.871	1.18	1.262	-	0.284	0.949	1.03
Temperature, Field	deg C	30$_{s6}$[A]	n/v	8.44	9.22	9.3	6.71	-	5.8	16.84	16.3
General Chemistry											
Alkalinity, Total (as CaCO3)	mg/L	$_{s16}$[A]	n/v	264	250	289	212	212	81.3 LK	108 LK	192
Chloride	mg/L	n/v	120[D] 640[E]	**151[D]**	**458[D]**	**156[D]**	**248[D]**	**246[D]**	**141[D]**	**201[D]**	**151[D]**
Dissolved Organic Carbon (DOC)	mg/L	n/v	n/v	1.68	5.0	2.7	2.9	2.9	2.88	15.6	6.88
Hardness (as CaCO3)	mg/L	n/v	n/v	276	281	321	215	219	286	109	227
Nitrate (as N)	mg/L	n/v	2.94[D] 550[E]	1.13	0.68	0.88	0.73	0.75	0.32	0.25	0.77
Nitrite (as N)	mg/L	n/v	0.06[D]	***< 0.075 MI***	***< 0.075***	< 0.015	***< 0.15***	***< 0.15***	***< 0.075 MI***	***< 0.150 MI***	***< 0.075 BQ***
pH	S.U.	6.5-8.5[A]	6.5-9.0[D]	7.89 EST	8.19 EST	8.11 EST	8.16 EST	8.17 EST	8.50 EST LK	7.81 EST LK	8.23
Sulfate	mg/L	n/v	n/v	11.6	15.0	12.3	11.2	11.2	7.0	15.5	11.3
Metals											
Aluminum	mg/L	0.075[C]	0.005/0.1$_{VAR1}$[D]	0.023	0.010	0.029	**0.149[CD]**	**0.151[CD]**	**2.75[CD]**	**2.40[CD]**	0.058
Calcium	mg/L	n/v	n/v	82.5	83.3	102	68.9	70.3	79.6	34.2	67.2
Iron	mg/L	0.3[A]	0.3[D]	**0.802[AD]**	**0.790[AD]**	**0.330[AD]**	0.276	0.273	**4.59[AD]**	**3.24[AD]**	**0.351[AD]**
Magnesium	mg/L	n/v	n/v	16.9	17.8	16.2	10.5	10.6	21.1	5.70	14.3
Manganese	mg/L	n/v	n/v	0.099	0.127	0.123	0.0699	0.0705	0.283	0.188	0.042
Potassium	mg/L	n/v	n/v	3.01	3.12	5.0	1.5	1.6	1.83	6.56	2.04
Sodium	mg/L	n/v	n/v	107	302	111	158	166	98.1	158	91.6

Sample Location	SW3-11						
Sample Date	14-Dec-11	26-Apr-12	5-Nov-12	12-Dec-12	10-Apr-13	29-May-13	30-Jul-13
Sample ID	SW3-11	SW3-11	SW3-11	SW3-11	SW3-11	SW3-11	SW3
Sampling Company	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC
Laboratory	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON
Laboratory Work Order	3111272	3203775	3210010	3211178	3303189	3304890	3306987
Laboratory Sample ID	356862	373120	398153	402618	416596	423064	430862
Sample Type							
Field Parameters							
Dissolved oxygen, Field	11.0	9.9	9.4	11.6	10.8	8.5	9.4
Oxidation Reduction Potential	-	-	153.7	72.0	-	118.0	155.1
pH, Field	8.06	8.02	8.03	7.89	8.80	7.62	8.08
Specific Conductance	3.492	2.405	2.37	2.804	0.212	0.363	1.93
Temperature, Field	4.19	7.01	6.3	3.89	5.8	15.23	14.8
General Chemistry							
Alkalinity, Total (as CaCO3)	406	393	411	357	36.3 LK	83.3 LK	366
Chloride	**842[DE]**	**510[D]**	**478[D]**	**722[DE]**	54.2	52.1	**478[D]**
Dissolved Organic Carbon (DOC)	1.57	5.8	4.7	4.4	4.92	6.07	3.26
Hardness (as CaCO3)	543	476	502	442	136	94.0	488
Nitrate (as N)	0.70	0.31	0.36	0.82	0.23	0.38	0.86
Nitrite (as N)	***< 0.150 MI***	***< 0.075***	***< 0.15***	***< 0.15***	< 0.015	< 0.015	***< 0.150 BQ***
pH	7.96 EST	8.21 EST	8.13 EST	8.16 EST	8.20 EST LK	7.97 EST LK	8.18
Sulfate	47.1	36.1	34.0	33.2	7.6	9.3	38.8
Metals							
Aluminum	< 0.010	< 0.010	< 0.010	< 0.010	**1.96[CD]**	**0.152[CD]**	< 0.030
Calcium	168	139	156	138	36.8	30.6	143
Iron	**1.19[AD]**	**2.07[AD]**	**0.890[AD]**	**0.996[AD]**	**3.65[AD]**	**0.395[AD]**	**0.542[AD]**
Magnesium	29.9	31.3	27.4	23.7	10.6	4.39	31.7
Manganese	0.231	0.248	0.276	0.248	0.153	< 0.050	0.109
Potassium	4.24	2.28	1.9	1.8	0.856	0.899	2.77
Sodium	545	353	281	410	40.0	37.2	271

Sample Location	SW4-11						
Sample Date	14-Dec-11	26-Apr-12	5-Nov-12	12-Dec-12	10-Apr-13	29-May-13	30-Jul-13
Sample ID	SW4-11	SW4-11	SW4-11	SW4-11	SW4-11	SW4-11	SW4
Sampling Company	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC
Laboratory	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON
Laboratory Work Order	3111272	3203775	3210010	3211178	3303189	3304890	3306987
Laboratory Sample ID	356866	373118	398154	402614	416598	423061	430865
Sample Type							
Field Parameters							
Dissolved oxygen, Field	11.4	10.4	9.6	13.2	10.4	8.1	9.6
Oxidation Reduction Potential	-	-	212.2	228.1	-	182.3	112.7
pH, Field	8.17	8.15	7.85	7.91	9.06	7.71	8.35
Specific Conductance	1.830	1.849	1.38	1.715	0.479	0.533	1.17
Temperature, Field	4.43	9.75	5.0	1.07	6.3	15.32	17.5
General Chemistry							
Alkalinity, Total (as CaCO3)	307	265	259	250	75.5 LK	84.0 LK	206
Chloride	**285[D]**	**347[D]**	**220[D]**	**316[D]**	96.2	93.2	**241[D]**
Dissolved Organic Carbon (DOC)	2.85	5.0	5.5	4.5	3.40	4.71	5.26
Hardness (as CaCO3)	554	517	379	358	192	139	318
Nitrate (as N)	2.08	1.35	1.75	1.63	0.54	0.47	1.33
Nitrite (as N)	***< 0.075 MI***	***< 0.075***	***< 0.15***	***< 0.15***	< 0.015	< 0.015	***< 0.075 BQ***
pH	8.07 EST	8.24 EST	8.23 EST	8.20 EST	8.04 EST LK	8.01 EST LK	8.26
Sulfate	159	187	66.9	99.2	12.8	27.2	63.2
Metals							
Aluminum	**0.076[C]**	0.050	0.062	**0.115[CD]**	**2.84[CD]**	**1.13[CD]**	0.067
Calcium	165	147	115	111	55.2	41.7	91.1
Iron	0.291	0.263	0.150	0.095	**4.54[AD]**	**1.62[AD]**	0.194
Magnesium	34.5	36.5	22.2	19.7	13.2	8.53	22.1
Manganese	0.067	0.071	0.0382	0.0385	0.222	0.105	0.032
Potassium	3.68	3.91	3.2	2.3	1.96	2.24	3.24
Sodium	188	218	149	189	64.2	59.4	139

See notes on last page.

Table 5
Surface Water Quality Results
2013 Pre-Construction Groundwater and Surface Water Monitoring
Proposed River Road Extension - King Street to Manitou Drive, Kitchener, ON

Sample Location				SW5-11							SW6-12	
Sample Date				14-Dec-11	26-Apr-12	5-Nov-12	12-Dec-12	10-Apr-13	29-May-13	30-Jul-13	5-Nov-12	5-Nov-12
Sample ID				SW5-11	SW5-11	SW5-11	SW5-11	SW5-11	SW5-11	SW5	SW6-12	SW6-12 DUPLICATE
Sampling Company				STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC
Laboratory				EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON
Laboratory Work Order				3111272	3203774	3210010	3211178	3303189	3304890	3306987	3210010	3210010
Laboratory Sample ID				356865	373117	398155	402613	416597	423060	430864	398156	398157
Sample Type	Units	PWQO	CCME									Field Duplicate
Field Parameters												
Dissolved oxygen, Field	mg/L	$_{s9}$[A]	n/v	11.5	10.4	12.4	12.8	9.5	8.6	9.9	11.2	-
Oxidation Reduction Potential	mV	n/v	n/v	-	-	231.4	160.7	-	149.1	79.8	56.9	-
pH, Field	S.U.	6.5-8.5[A]	n/v	8.16	8.08	7.37	7.86	8.83	7.67	8.30	**8.67[A]**	-
Specific Conductance	mS/cm	n/v	n/v	1.837	1.868	1.40	1.824	0.555	0.512	1.18	0.475	-
Temperature, Field	deg C	30_{s6}[A]	n/v	4.25	9.48	4.9	1.04	6.3	14.94	17.6	4.0	-
General Chemistry												
Alkalinity, Total (as CaCO3)	mg/L	$_{s16}$[A]	n/v	304	259	260	243	83.1 LK	79.7 LK	205	122	127
Chloride	mg/L	n/v	120[D] 640[E]	**288[D]**	**354[D]**	**226[D]**	**353[D]**	117	85.7	**243[D]**	60.2	60.7
Dissolved Organic Carbon (DOC)	mg/L	n/v	n/v	2.92	5.2	5.6	5.0	3.69	4.74	4.32	6.9	6.9
Hardness (as CaCO3)	mg/L	n/v	n/v	554	517	339	350	199	132	314	129	117
Nitrate (as N)	mg/L	n/v	2.94[D] 550[E]	2.03	1.37	1.73	1.62	0.55	0.43	1.34	< 0.10	< 0.10
Nitrite (as N)	mg/L	n/v	0.06[D]	***< 0.075 MI***	***< 0.075***	***< 0.15***	***< 0.15***	< 0.015	< 0.015	***< 0.075 BQ***	< 0.015	< 0.015
pH	S.U.	6.5-8.5[A]	6.5-9.0[D]	8.07 EST	8.22 EST	8.21 EST	8.18 EST	8.01 EST LK	7.96 EST LK	8.23	8.14 EST	8.12 EST
Sulfate	mg/L	n/v	n/v	159	183	66.6	97.9	14.2	28.2	62.8	5.0	5.1
Metals												
Aluminum	mg/L	0.075[C]	$0.005/0.1_{VAR1}$[D]	0.064	0.043	0.060	**0.097[C]**	**3.13[CD]**	**1.12[CD]**	0.066	0.027	0.028
Calcium	mg/L	n/v	n/v	165	146	103	109	57.2	39.5	89.8	38.9	35.3
Iron	mg/L	0.3[A]	0.3[D]	0.278	0.253	0.117	0.056	**4.98[AD]**	**1.6[AD]**	0.184	**0.320[AD]**	**0.316[AD]**
Magnesium	mg/L	n/v	n/v	34.4	37.0	19.9	18.9	13.6	8.14	21.8	7.84	7.09
Manganese	mg/L	n/v	n/v	0.062	0.066	0.0320	0.0364	0.244	0.105	0.026	0.0094	0.0399
Potassium	mg/L	n/v	n/v	3.96	4.02	2.9	2.3	2.09	2.18	3.24	1.4	1.3
Sodium	mg/L	n/v	n/v	188	225	152	204	71.4	53.6	139	44.0	40.5

Sample Location	SW6-12			SW12-12			SW14-12			SW15-13		
Sample Date	12-Dec-12	29-May-13	30-Jul-13	10-Apr-13	29-May-13	31-Jul-13	10-Apr-13	29-May-13	31-Jul-13	10-Apr-13	29-May-13	31-Jul-13
Sample ID	SW6-11	SW6-12	SW6	DP12-12	SW12-12	DP12	DP14-11	SW14-13	DP14	DP15-13	SW15-13	DP15
Sampling Company	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC
Laboratory	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON	EELS-WON
Laboratory Work Order	3211178	3304890	3306987	3303189	3304890	3307005	3303189	3304890	3307005	3303189	3304890	3307005
Laboratory Sample ID	402617	423067	430866	416600	423066	430929	416599	423063	430928	416603	423065	430927
Sample Type												
Field Parameters												
Dissolved oxygen, Field	9.9	6.6	6.1	6.3	1.5	2.5	11.0	6.6	7.9	9.9	6.9	7.0
Oxidation Reduction Potential	231.8	131.4	105.1	-	122.0	47.5	-	120.0	-30	-	96.0	-25
pH, Field	7.62	7.75	8.00	8.75	7.08	6.94	9.69	7.75	7.76	8.97	7.61	6.74
Specific Conductance	0.796	0.993	0.82	0.174	0.314	0.271	0.261	0.592	0.27	0.744	1.479	2.09
Temperature, Field	1.83	15.86	18.3	6.9	15.76	17.4	5.9	16.76	22.0	5.9	13.18	13.6
General Chemistry												
Alkalinity, Total (as CaCO3)	147	164 LK	180	65.5 LK	106 LK	118	28.5 LK	70.7	75.2	183 LK	294 LK	344
Chloride	**145[D]**	**205[D]**	**167[D]**	11.1	25.7	21.5	35.9	47.7	39.5	**123[D]**	**264[D]**	**516[D]**
Dissolved Organic Carbon (DOC)	5.8	8.24	9.21	14.3	31.7	27.1	2.46	4.37	6.75	6.19	4.06	1.63
Hardness (as CaCO3)	173	173	208	68.0	117	125	34.0	56.0	68.0	227	391	521
Nitrate (as N)	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	0.16	0.12	< 0.10	0.56	0.19	0.48
Nitrite (as N)	< 0.015	***< 0.150 MI***	***< 0.075 BQ***	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	***< 0.150 MI***	***< 0.075 BQ***
pH	7.97 EST	8.14 EST LK	7.94	7.37 EST LK	7.59 EST LK	7.49	8.33 EST LK	7.93	7.95	7.92 EST LK	8.16 EST LK	7.91
Sulfate	7.7	4.2	5.1	3.1	1.5	< 0.5	4.6	4.8	2.7	15.8	24.2	35.0
Metals												
Aluminum	0.041	**0.109[CD]**	0.072	< 0.030	< 0.050	< 0.03	**1.20[CD]**	**0.162[CD]**	**0.140[CD]**	**0.397[CD]**	< 0.050	**0.311[CD]**
Calcium	54.0	49.2	57.6	17.0	29.9	34.0	13.6	22.4	27.1	59.4	103	138
Iron	**0.560[AD]**	**0.626[AD]**	**0.651[AD]**	0.105	**0.467[AD]**	0.249	**1.69[AD]**	**0.304[AD]**	**0.907[AD]**	**0.648[AD]**	0.144	**0.472[AD]**
Magnesium	9.16	12.1	15.5	6.26	10.2	9.65	< 3.00	< 3.00	< 3.00	19.1	32.6	42.8
Manganese	0.631	< 0.050	0.077	0.044	0.166	0.097	0.079	0.051	0.041	0.054	< 0.050	0.094
Potassium	3.6	1.52	1.91	7.47	12.6	9.55	0.638	1.01	0.957	1.46	1.02	1.60
Sodium	87.6	136	104	5.20	13.7	12.3	28.8	39.2	28.4	70.0	161	262

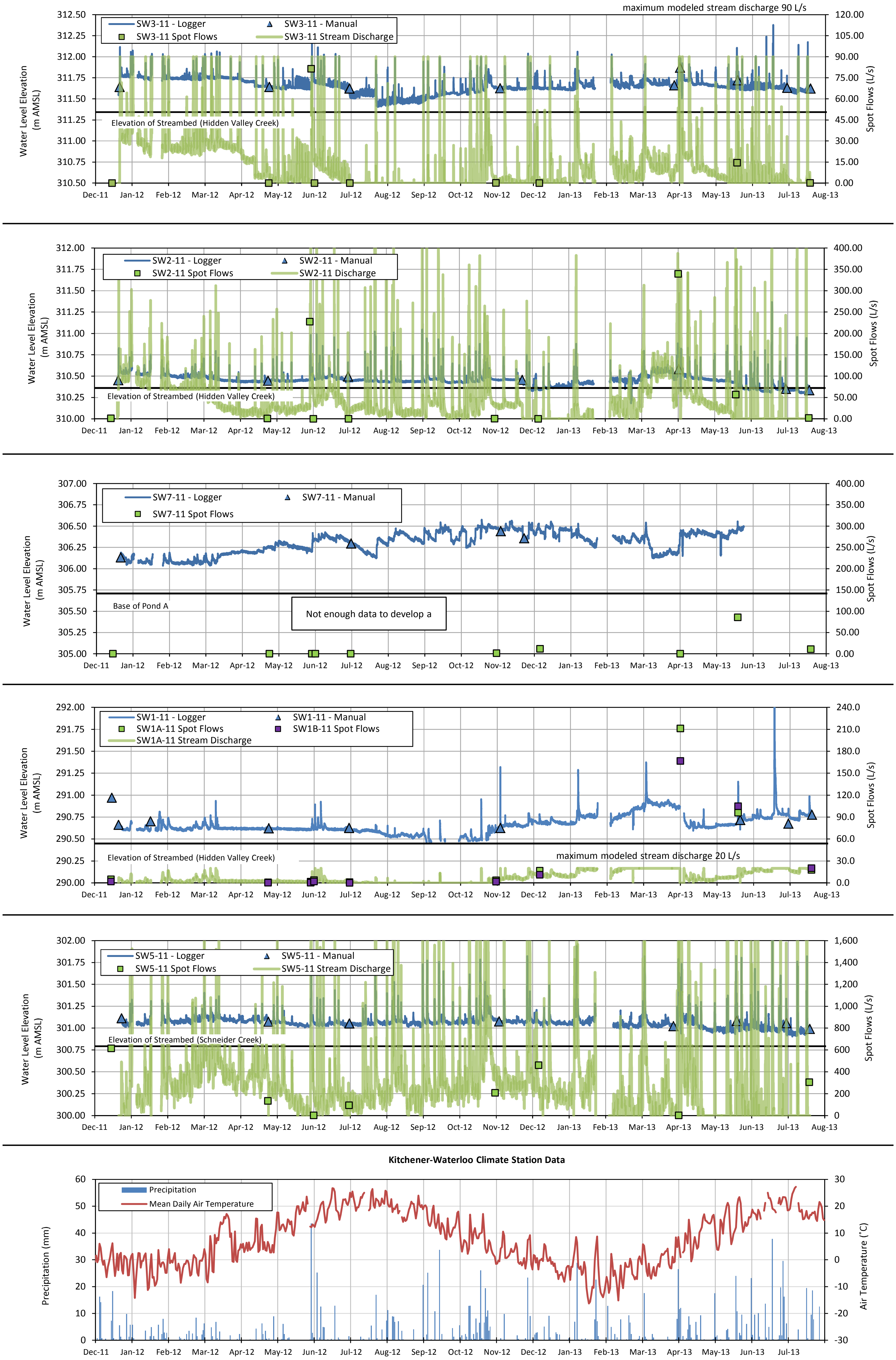
Notes:

PWQO	Provincial Water Quality Objectives of the Ministry of Environment and Energy, July 1994, reprinted February 1999
A	PWQO Table 2
B	PWQO Table 2 - Calc
C	PWQO Table 2 - Interim
CCME	Canadian Council of Ministers of the Environment
D	Canadian Environmental Quality Guidelines, Canadian Water Quality Guidelines for the Protection of Aquatic Life - Freshwater Aquatics Long Term
E	Canadian Environmental Quality Guidelines, Canadian Water Quality Guidelines for the Protection of Aquatic Life - Freshwater Aquatics Short Term
6.5[A]	Concentration exceeds the indicated standard.
15.2	Concentration was detected but did not exceed applicable standards.
< 0.50	Laboratory estimated quantitation limit exceeded standard.
< 0.03	The analyte was not detected above the laboratory estimated quantitation limit.
n/v	No standard/guideline value.
-	Parameter not analyzed / not available.
s6	Temperature at the edge of a mixing zone shall not exceed natural ambient water temperature by more than 10 deg C. The maximum temperature of the receiving body of water shall not exceed 30 deg C. See PWQO pg 25.
s9	The PWQO for dissolved oxygen is both temperature and biota dependent. See page 17 of MOE (1994).
s16	Alkalinity should not be decreased by more than 25% of the natural concentration.
VAR1	Variable, 5 µg/L if pH < 6.5 and 100 µg/L if pH > 6.5
EST	Estimated value
LK	Sample filtered for pH and Alkalinity - filtrate analyzed.
MI	Detection limit was raised due to matrix interferences.
BQ	Reporting limits corrected with a dilution factor due to a matrix interference.

Table 4
Spot Flow Measurements
2013 Pre-Consruction Groundwater and Surface Water Monitoring
Proposed River Road Extension - King Street to Manitou Drive, Kitchener, ON

Location	Stream Discharge (L/s)						
	SW1A-11	SW1B-11	SW2-11	SW3-11	SW4-11	SW5-11	SW7-12
12-Oct-11	3.8	0.9	-	-	-	-	-
15-Dec-11	4.8	1.7	1.2	-	337	613	-
26-Apr-12	0.63	0.06	0.50	-	167	134	-
1-Jun-12	1.4	0.10	228	81	3,060	4,671	-
4-Jun-12	3.4	1.7	-	-	-	-	-
4-Jul-12	0.68	-	0.04	-	94	93	-
5-Nov-12	3.2	1.5	0.46	0.05	210	208	1.2
12-Dec-12	16	11	-	-	242	460	11
10-Apr-13	211	167	339	282	-	-	-
29-May-13	96	105	57	14	2,188	3,359	85
30-Jul-13	17	20	1.6	0.12	195	304	11

Notes:
SW7-12 was added to the monitoring program in November 2012 -
-: Stream discharge not measured or flow was too high to safely measure.



Notes:

Rating curve for SW5-12 was not sufficient for stage data less than 301 m AMSL.

Client/Project

Proposed River Road Extension
King Street To Manitou Drive, Kitchener, ON
Regional Municipality of Waterloo

Figure No.

7

Title **Surface Water Elevation and Stream Flows**

Stantec

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Appendix A3

Miscellaneous References

Schedule B: SOURCE WATER PROTECTION LAND USE CATEGORIES

Category 'A'
▪ Waste treatment and disposal facilities, including lagoons, landfills, communal/municipal sewage treatment facilities and including large sewage vaults at sewage pumping stations, but not including facilities regulated under the Nutrient Management Act.
▪ Salvage yards, including automobile wrecking yards or premises
▪ Bulk storage of hazardous chemicals and hazardous substances (as listed in O.Reg. 347 under the Environmental Protection Act), including bulk storage of oil, gasoline or petroleum products, and including transportation terminals for these substances/chemicals (including truck/trailer/container parking, washing or cleaning depots)
▪
Category 'B'
▪ Bulk storage of road salt and snow disposal sites
▪ Primary metal manufacturing, including iron and steel mills and ferro-alloy manufacturing; steel product manufacturing from purchased steel; alumina and aluminum production and processing; non-ferrous metal production and processing; and foundries
▪ Manufacturing of fabricated metal products, including manufacturing of unfinished metal products and metal finishing operations
▪ Manufacturing and assembly of transportation equipment, including motor vehicles and parts, aerospace products and parts, rail cars, ships and boats
▪ Manufacturing of machinery, including agricultural, commercial, industrial, and other machinery
▪ Chemical manufacturing including chemicals; resins; fertilizers, pesticides and other agricultural chemicals; pharmaceutical and medicines; paint, coating and adhesives; inks and other chemicals but excluding soap and cleaning compound manufacturing. Including manufacturing, packaging, repackaging, and bottling. Excludes uses involving bulk storage of hazardous materials which are included under Category 'A'
▪ Manufacturing of petroleum and coal products, including manufacturing of asphalt materials. Excludes uses involving bulk storage of hazardous materials which are included under Category 'A'
▪ Manufacturing of electronic components such as semiconductors, printed circuit boards, and cathode ray tubes
▪ Manufacturing of electrical equipment, appliances and components
▪ Commercial or industrial dry cleaning of textiles and textile products, excluding depots not performing on-site dry cleaning
▪ Manufacturing of leather and allied products including footwear

▪ Wood and wood product preservation and treatment
▪ Gasoline stations and other retail establishments with gasoline sales
▪ Wholesale/distributing of cleaning products, pesticides, herbicides, fungicides and chemicals
Category 'C'
▪ Manufacturing of rubber products
▪ Manufacturing of soap, cleaning compounds and toilet preparations
▪ Textile and fabric finishing and fabric coating
▪ Manufacturing of plastic products
▪ Manufacturing of wood products including wood furniture, and excluding wood preservation
▪ Manufacturing of glass and glass products
▪ Manufacturing of paper and paper products including newsprint and boxes
▪ Printing and related support activities, excluding business support services such as photocopy services
▪ Repair and Maintenance of automobiles and automotive machinery, electronic equipment, industrial and commercial machinery, and personal and household goods repair
▪ Golf courses
▪ Airports, train and public transit terminals, except terminals with no fuel storage or transfer of shipped goods or materials
▪ Medical, health and other laboratories (other than clinics generally associated with commercial plazas)
▪ Miscellaneous manufacturing not included elsewhere, including jewellery, silverware, medical equipment and signs
▪ Recycling, recovery, or remanufacturing of materials including the collection, processing, manufacturing, or reuse of post-consumer or post-industrial materials, not including recycling or disposal of hazardous materials, and not including salvage yards or facilities with outdoor operations which are Category 'A' uses
Category 'D'
▪ Underground parking garages
▪ *Geothermal wells*
▪ *Mineral aggregate operations* including *wayside pits and quarries*