PALMER ENVIRONMENTAL CONSULTING GROUP INC.

74 Berkeley Street, Toronto, ON, M5A 2W7 *t* 647 795 8153

Class Environmental Assessment for Water and Wastewater Servicing in the Community of Nobleton

Background Hydrogeological Assessment

PECG Project #

1704602

Prepared For

Black & Veatch

April 18, 2018

PALMER ENVIRONMENTAL CONSULTING GROUP INC.

74 Berkeley Street, Toronto, ON, M5A 2W7 ***t*** *647 795 8153*

April 18, 2018

Dania Chehab, M.Eng., P.Eng.
Civil Engineer
Black & Veatch
50 Minthorn Blvd, Suite 501
Markham, ON L3T 7X8

Dear Ms. Chehab:

Re: Class Environmental Assessment for Water and Wastewater Servicing in the Community of Nobleton – Background Hydrogeological Assessment

Palmer Environmental Consulting Group Inc. (PECG) is pleased to provide Black & Veatch with the attached report describing the results of our Background Hydrogeological Assessment to support Class Environmental Assessment for Water and Wastewater Servicing in the Community of Nobleton, Ontario. Nobleton is currently supplied by three production wells (PW-2, PW-3, and PW-5), which are permitted under the Ministry of the Environment and Climate Change (MOECC) Permit To Take Water (PTTW) Number 0550-9PPRJ9.

This report focuses on characterizing the geological and hydrogeological conditions of the study area and assessing the existing water supply capacity through a desktop investigation. This includes characterization of local and regional geological and hydrogeological conditions, an assessment of water taking rates and water level drawdown from municipal supply wells PW-2, PW-3, and PW-5 between January 2012 and December 2017, and analysis of drawdown and the radius of influence within the York Region monitoring well network for the shallow and deep aquifer systems. A summary of Source Water Protection findings under the *Clean Water Act (2006),* are also described for the Nobleton area.

Based on a review of Nobleton water taking and drawdown data between January 2012 and December 2017, the summer of 2016 showed a greatly increased groundwater demand relative to the previous 2012 to 2015 period. The peak groundwater usage in 2016 was 4,433 m^3/day which is more than 99% of the permitted capacity of 4,460 m^3/day.

While the Nobleton water supply has a redundancy of 2,496 m^3/day and a “firm capacity” of 4,460 m^3/day, additional permitted water supply capacity will be required to meet the 2031 population forecast of 10,800 persons, which is a 96% increase from the current population of 5,500. This study provides recommendations for hydrogeological studies to support identifying and permitting additional water supply capacity as part of the Class EA. These studies include step drawdown testing to increase the water taking rates, an assessment of interference effects between the three production wells, and a groundwater resources exploration program to identify a potential location for a new production well.

Please feel free to contact us if you have question or comments on this submission. Thank you for the opportunity to work with your team on this project.

Yours truly,

Palmer Environmental Consulting Group Inc.

J. Cole

Jason Cole, M.Sc., P.Geo.
Principal, Senior Hydrogeologist

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PALMER ENVIRONMENTAL CONSULTING GROUP INC.

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1. Introduction and Background

Palmer Environmental Consulting Group Inc. (PECG) was retained by Black & Veatch to complete a Background Hydrogeological Assessment to support Class Environmental Assessment for Water and Wastewater Servicing in the Community of Nobleton, Ontario (the "study area"). The purpose of this Schedule C Class Environmental Assessment is to assess alternative water and wastewater servicing solutions and select the preferred alternative (s) to accommodate population growth to 10,800 persons in the Nobleton community as designated in the Township of King's Nobleton Community Plan and intensification targets to 2031.

The community of Nobleton is centered around the intersection of King Road (Regional Road 11) and Regional Road 27 (formerly Highway 27) in the western part of York Region (**Figure 1**). Nobleton is located approximately 15 km north west of Vaughan, Ontario, and the study area covers an area of approximately 12 km^2. The study area for this investigation is bound to the limits of 8th Concession Road to the east, 16th Sideroad to the north, Concession Road 10 to the west and south of Diana Drive but north of King Vaughan Road to the south. Currently, land use within the study area is primarily agricultural, with a small portion of commercial development along Highway 27 (Nobleton Plaza) and King Road. Low density residential and commercial development is currently present around the city centre.

At present, the community of Nobleton is serviced within a single water pressure district. Nobleton is supplied by three production wells: PW-2, PW-3, and PW-5. These wells are permitted under the Ministry of the Environment and Climate Change (MOECC) Permit To Take Water (PTTW) Number 0550-9PPRJ9, with a maximum daily water taking from any combination of the wells of 4,446 m^3/day. System storage capacity is provided by the Highway 27 and Nobleton elevated tanks at 1.8 Million Litres (ML) and 2.0 ML, respectively.

The purpose of this background hydrogeological assessment is to characterize the existing geological and hydrogeological of the study area and assess the current water supply capacity through a desktop investigation, to determine if the existing serviceable capacity is sufficient to support Nobleton's projected population growth to 2031. This investigation includes local and regional physiography, quaternary geology and bedrock geology, identification of hydrostratigraphic units (i.e., aquifers and aquitards), location of private water wells, characterization of groundwater levels and chemistry based on existing records, an assessment of the Source Water Protection policies and findings under the *Clean Water Act (2006)*, and a detailed assessment of the water taking and water level drawdown data from the municipal water supply wells between January 2012 and December 2017.

Recommendations for additional hydrogeological investigations or changes to the existing PTTW will be made, if required, and provide the framework for these studies. This report is not intended to support a potential future groundwater exploration program or municipal water supply well investigation/ permitting should that be required. If required, these additional work programs will be provided in a separate document specific for each study.

LEGEND

- Municipal Production Well
- Major Road
- Watercourse
- Contour (5 m Interval)
- Study Area

N

0 0.5 1
kilometres

Scale 1:30000 NAD 1983 UTM Zone 17N

DATA SOURCES: Natural Resources Canada (National Road Network - Ontario), Ontario Ministry of Natural Resources and Forestry (Ontario Hydrographic Network), Ontario Municipal Affairs (Municipal boundaries). Base imagery ©2017 Google (CNES / Airbus, DigitalGlobe, First Base Solutions, Landsat / Copernicus).

Client: Black & Veatch
Project: Nobleton Water and Wastewater

PREPARED BY:

PALMER ENVIRONMENTAL CONSULTING GROUP INC.

DRAWN: B. Elder
CHECKED: B. Katanchi
PROJECT: 170461
DATE: Feb 10, 2018

Study Area

FIGURE 1

Document Path: C:\Egnyte\Shared\Projects\Active\17046 - Black & Veatch\170461 - Nobleton W&WW\Mapping\mxd\170461_Figure1_StudyArea.mxd

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2. Existing Geological and Hydrogeological Conditions

2.1 Physiography, Topography and Drainage

The study area is located within the South Slope physiographic region as defined by Chapman and Putnam (1984). The Oak Ridges Moraine (ORM) physiographic region is located immediately north to northeast outside the of the study area (**Figure 2**).

The South Slope physiographic region begins at a sharp break-in-slope on the south side of the ORM and slopes downward towards Lake Ontario (Chapman and Putnam, 1984). The South Slope is a gently rolling till plain, characterized by numerous drumlins oriented upslope. Upon deglaciation, about 12,000 years ago, meltwater streams cut sharp valleys in the till, locally exposing the underlying ORM sediments near the northern boundary of the study area.

The main surface water feature in the study area is the East Humber River. The East Humber River is located along the eastern portion of the Nobleton Community. The East Humber River joins the Main Branch of the Humber River approximately 14 km to the south of Nobleton. A series of small tributaries are present within the study area, which flow easterly across the south slope, and discharge into the East Humber River.

Ground surface elevation decreases to the south towards Lake Ontario. The topography is generally gently rolling dropping from approximately 280 masl in the north to about 230 masl in the south. The community of Nobleton is located on a gentle north-south trending ridge with elevations in the range of 265 to 275 masl (MMM, 2007).

2.2 Quaternary and Bedrock Geology

Overburden thickness in the study area is approximately 250 m (Earthfx, 2013). At surface, the quaternary geology of the study area, as described by Ontario Geological Survey (OGS) mapping (Chapman and Putnam, 1984), primarily consists of Halton Till, which is described as a silty to clayey silt till (**Figure 3**). The Humber valley lands located near the study area are mapped with recent alluvial deposits (Barnett et al., 1991; Earthfx, 2013). Bedrock geology for the study area is presented on **Figure 4**.

The following summarizes the quaternary geology of the study area and is largely based on the work by Kassenaar and Wexler (2006) and presented in the York Region Tier 3 Water Budget and Water Quantity Assessment (Earthfx, 2013). **Appendix A** and **B** present the regional stratigraphy and local cross sections for the Nobleton area.

Surficial Deposits, Glaciolacustrine, Modern Alluvium & Channel Deposits

Surficial deposits are dominated by glaciolacustrine and lacustrine deposits formed during and after the final retreat of the Wisconsinan ice sheets (~12,500 years ago; Kassenaar and Wexler, 2006). These deposits range from massive to laminated clay and silt deposited in deep water low energy environments to sand and gravel deposited along former shorelines (i.e. Lake Iroquois). Also present at surface are recent alluvial deposits of silt, sand and gravel that are restricted primarily to the valley lands associated with Humber River valley lands.

Within the study area, surficial deposits lying stratigraphically above the Halton Till are dominated by low permeability fine-textured glaciolacustrine silts and clays. Also present at surface are recent alluvial deposits of silt, sand and gravel that are restricted primarily to the valley lands associated with Humber River valley lands.

Halton Till

The Halton Till represents the final advance of ice northwards out of the Lake Ontario basin at the end of the Wisconsinan glaciation approximately 13,000 years ago (Eyles, 2002). It is an extensive diamicton with varying texture ranging from sandy silt till to silty clay till (Earthfx, 2013). Halton Till is present over most of the southern portion of the York region. On a regional scale, the Halton Till acts as a surficial aquitard, playing a significant role in inhibiting groundwater recharge to the Oak Ridges Moraine Aquifer Complex (ORAC) (Earthfx, 2013).

Within the study area the Halton Till has a relatively fine-grained matrix (sandy to clayey silt), and its presence is widespread in the area. Typical thickness is interpreted at between 10 to 20 m up to 40 m in thickness in the area of the high ground at the northwest of Nobleton. The Halton Till may be utilized as an aquifer for shallow wells completed within localized granular seams found within the till. The Halton Till also forms the uppermost confining aquitard in the study area.

Oak Ridges Moraine

The Oak Ridges Moraine was formed approximately 13,300 years ago (Eyles, 2002). During a brief ice-free interval following its deposition, coarse sand and gravel sediments of the Oak Ridges Moraine were dispersed by rivers flowing on the ice front. These interstadial deposits are typically less than 5 m in thickness (up to a maximum thickness of 95 m beneath the crest of the moraine but thinning rapidly towards its margins), and form a widespread, discontinuous subsurficial layer that extends beyond the boundary of the Oak Ridges Moraine.

At surface, the Oak Ridges Moraine terrain exhibits a hummocky, knob and basin, relief with hills composed of sand and gravel. However, deposits are not present at surface within the study area (**Figure 3**), but near-surface ORM sediments that extend into the study area form an upper aquifer. Interstadial sand deposits are typically thin and discontinuous and occur between the Halton and Newmarket Till units. Due to the high permeability, the ORAC acts as significant recharge source to underlying aquifers (Earthfx, 2013). The ORAC contains few surface water channels, however supplies groundwater discharge to streams that drain till plains to the south and north (Earthfx, 2013). The ORAC is an important aquifer regionally.

Tunnel Channel Deposits

Late stage (~13,500 years ago) subglacial meltwater floods during the Late Wisconsin resulted in the incision of tunnel valleys and channels within the underlying sediment (Barnett et al., 1998; Earthfx, 2013). These channels were subsequently filled with alluvium such as boulders, cobbles, gravels, sands and silts as flood flows decreased. Such deposits are significant hydrogeological features as they provide both spatially discrete aquifers which can be up to several metres thick and permeable deposits which can increase connectivity between regional aquifers.

Within the Nobleton area, the Newmarket Till (described below) is thought to have been eroded in some areas by subglacial meltwater which formed a series of broad tunnel channel valleys filled with thick sand and silt deposits. Kassenaar and Wexler (2006) and Earthfx (2013) have suggested that three such channels, forming part of a major channel system that originates in the vicinity of Holland Landing are located nearby to Nobleton. Two of these tunnel channels are located within the study area (**Appendix B**), one occupying approximately 1 km^2 of the most northeast boundary and approximately 400 m^2 in the most northwest boundary. As mentioned above, these features act as significant hydrogeological controls, increasing connectivity between regional aquifers or acting as spatially discrete local aquifers.

Newmarket Till

Newmarket Till is a massive, over-consolidated Stony Till (silty sand to sandy silt matrix) deposited by the Laurentide Ice Sheet approximately 20,000 years ago (Eyles, 2002). As a whole, the Newmarket Till is considered to be an aquitard unit that separates the ORAC from the underlying Thorncliffe Aquifer. The Newmarket Till is subdivided into units, which includes Upper Newmarket Till (UNT), Inter-Newmarket Sediments (INS), and the Lower Newmarket Till (LNT). The UNT and LNT units are considered aquitards composed on the aforementioned Stony Till, whereas the INS is considered an aquifer composed of silt to gravelly sands of glaciolacustrine or glaciofluvial origin.

Within the study area the permeable INT unit is absent and the less permeable UNT and LNT units are merged into one Newmarket Till unit which is shown as a discontinuous layer up to approximately 30 m thick (Earthfx, 2013). This till is reported to include thin interbeds of sands and silts, boulder pavements, fractures and joints as well as discontinuous sand seams on the order of 1 to 2 m thickness. Infrequently, the till may also contain thin rythmites or isolated clay laminations. As the ORAC is absent, it may be difficult to distinguish Halton Till from Newmarket Till based on MOECC Water Well Records.

Thorncliffe Formation

The Thorncliffe Formation consists of glaciofluvial to glaciolacustrine deposits that extend under most of York Region (Earthfx, 2013). The unit is generally comprised of laminated clay, silt, and sand, is considered a major regional aquifer due to its extent and thickness (Karrow, 1967). The lower part of the formation is often identified by silt-clay rythmites (varves). This unit was generally deposited by glacial meltwater entering a deep ice-dammed lake in the area of present day Lake Ontario, between approximately 45,000 years ago (Eyles, 2002). The formation is noted for its considerable variation in the type of sediments, both locally and regionally.

The Thorncliffe Aquifer is interpreted as the second stratigraphic aquifer in the Nobleton area. Examination of well records of the area suggests many domestic wells are completed in the Thorncliffe aquifer. Domestic wells that are completed in the Thorncliffe Aquifer appear to be screened within the upper portions of this aquifer.

Sunnybrook Drift

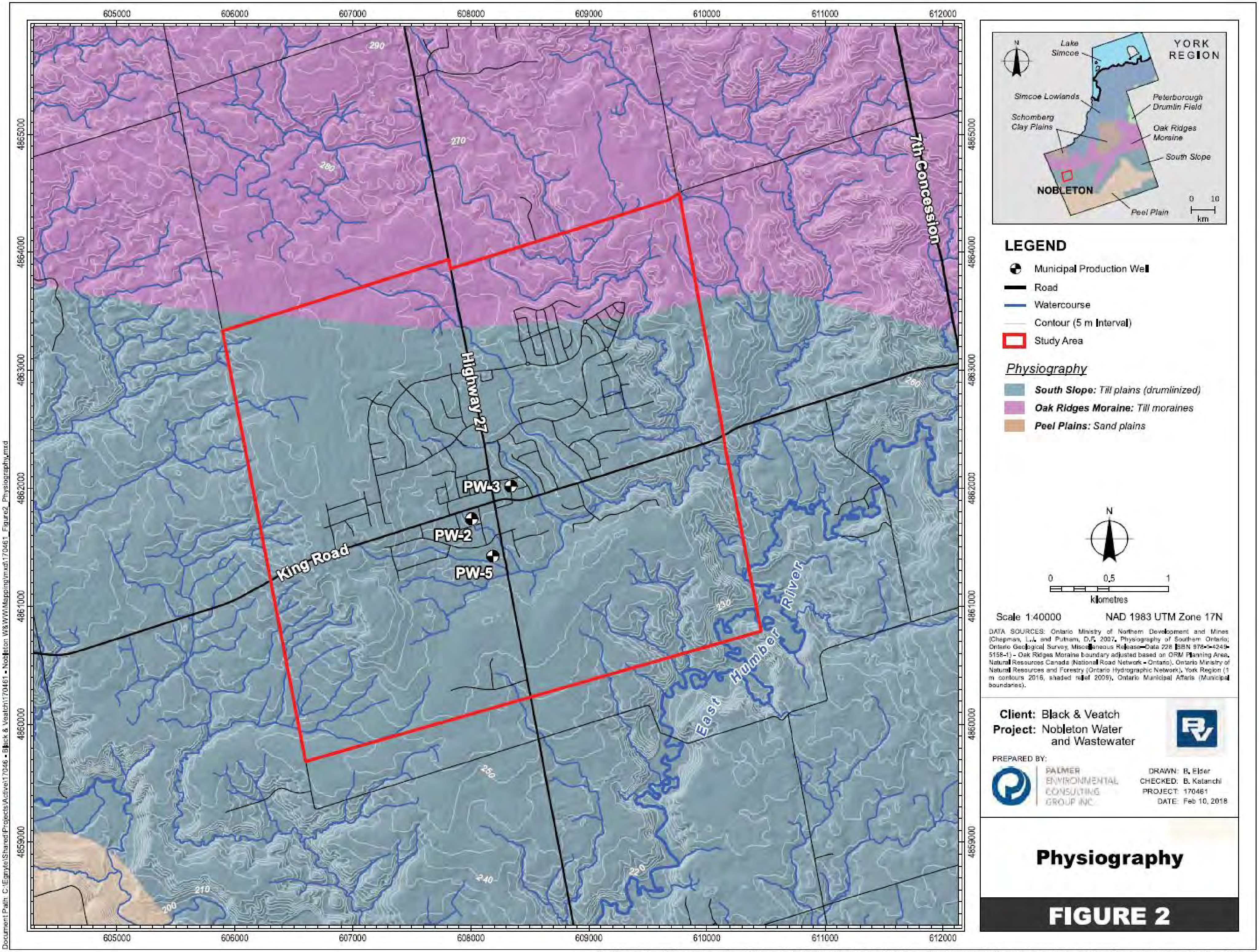
Like the Thorncliffe Formation, the Sunnybrook Drift is a regionally extensive unit. The Sunnybrook Drift is typically described as a clast-poor mud (silt and clay) deposited on the floor of a glacially dammed lake or formed by the overriding of pre-existing lake sediments by advancing ice about 45,000 years ago (Eyles, 2002). It is generally less than 10 to 20 m in thickness.

Like the Thorncliffe Formation, the Sunnybrook Drift is a regionally extensive unit and is found within the study area according to Earthfx (2013). The Sunnybrook Drift in the study area is around 10 – 20 m thick (Earthfx, 2013).

Scarborough Formation

The Scarborough Formation marks the start of the Wisconsinan glaciation approximately 60,000 years ago and is interpreted as a fluvio-deltaic system fed by large braided meltwater streams and rivers draining from an advancing ice sheet (Eyles, 2002). The Formation exhibits upward coarsening and increasing thickness of layers from clay-rich rhythmites to channelized cross-bedded sands (Kelly and Martini, 1986). A large amount of sand is present in the upper portion of the formation and is likely the result of glacial outwash fans. The Scarborough Aquifer is interpreted to underlie much of York Region. York has a number of wells with screen located in an interpreted Scarborough Aquifer.

Appreciable thicknesses of the Scarborough Formation are observed in bedrock lows and valleys including the Laurentian valley and its tributaries. Two such deep tributaries are interpreted within the study area, in south-southwest Nobleton and east of the community. Over the interpreted bedrock valleys, the Scarborough Aquifer is mapped on the order of between 60 to 80 m thickness (Earthfx, 2013).



Physiography

FIGURE 2

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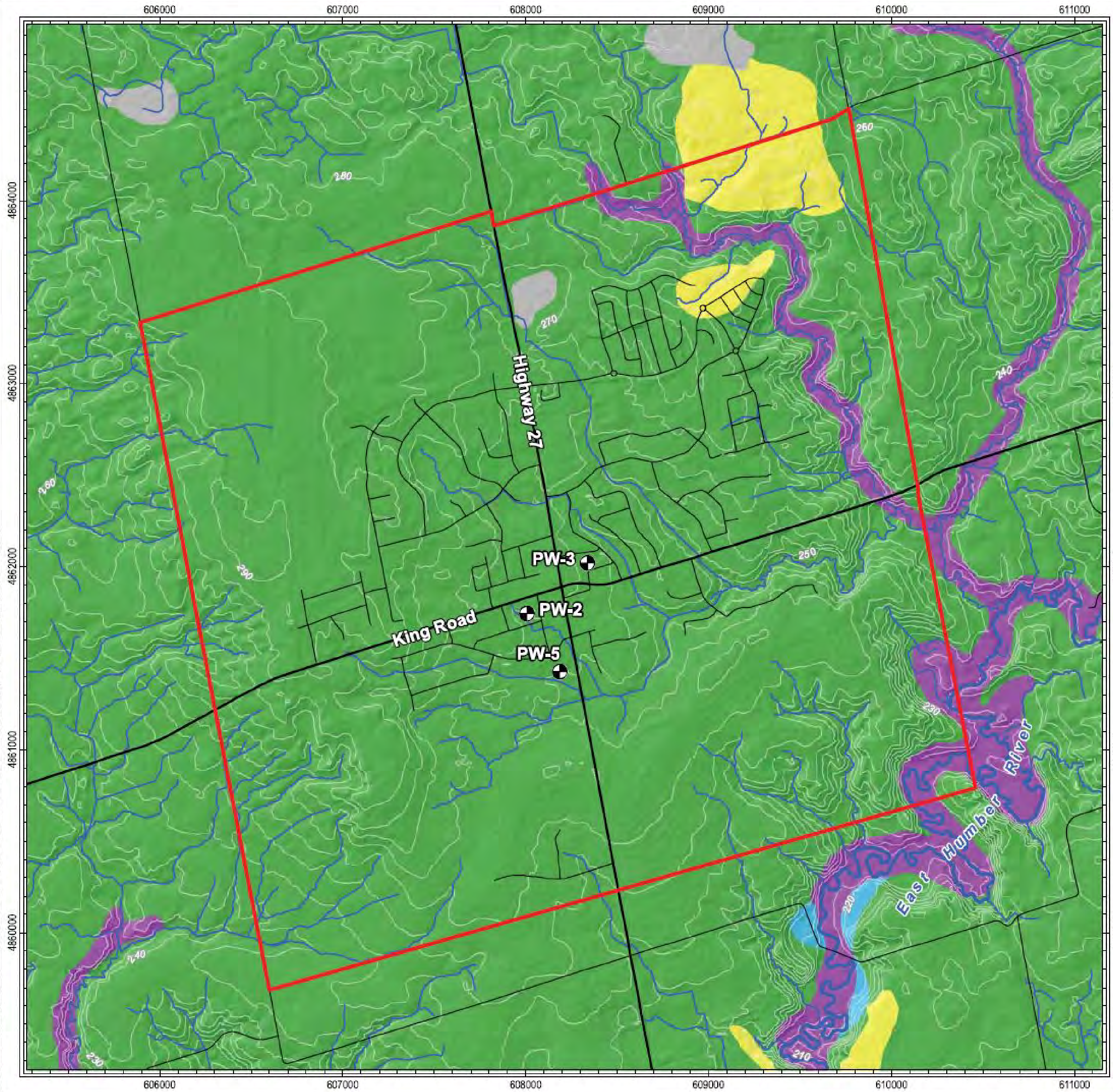

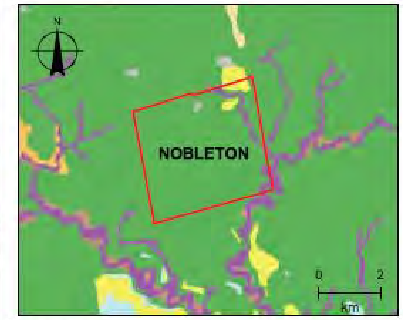

LEGEND

- Municipal Production Well
- Road
- Watercourse
- Contour (5 m Interval)
- Study Area

Surficial Geology

- ***Organic Bog Deposits:*** *peat, muck, marl*
- ***Modern Alluvium:*** *silt, sand, gravel*
- ***Deltaic and Lacustrine Sand:*** *sand, some silt and gravel*
- ***Halton Till:*** *brown loam to silt loam till*

N

0 0.5 1
kilometres

Scale 1:30000 NAD 1983 UTM Zone 17N

DATA SOURCES: Ontario Ministry of Northern Development and Mines (Ontario Geological Survey 2010. Surficial geology of Southern Ontario; Ontario Geological Survey, Miscellaneous Release—Data 128-REV), Natural Resources Canada (National Road Network - Ontario), Ontario Ministry of Natural Resources and Forestry (Ontario Hydrographic Network), York Region (1 m contours 2016, shaded relief 2009), Ontario Municipal Affairs (Municipal boundaries).

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Project: Nobleton Water and Wastewater

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DRAWN: B. Elder
CHECKED: B. Katanchi
PROJECT: 170461
DATE: Feb 10, 2018

Surficial Geology

FIGURE 3

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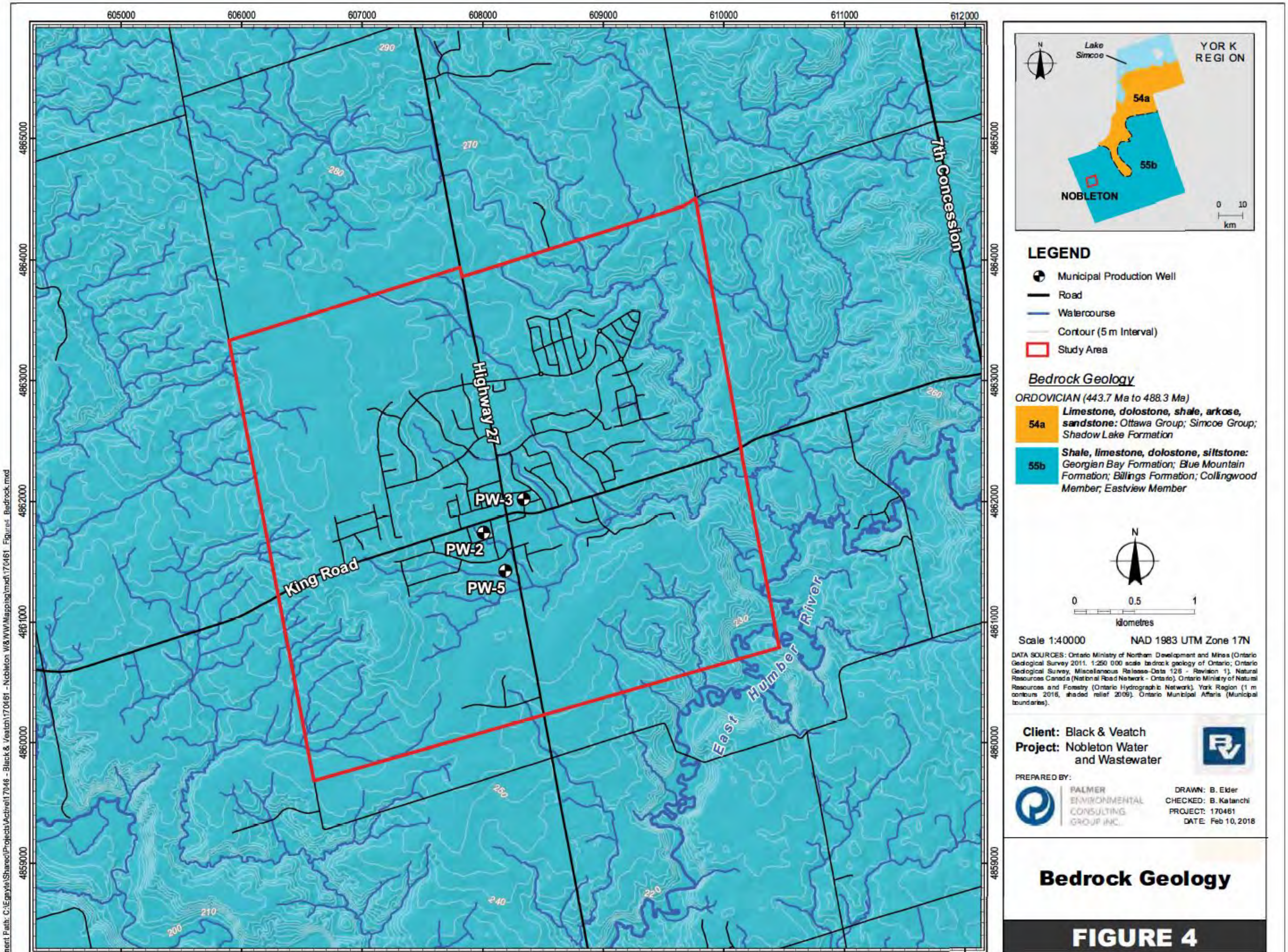

Bedrock Geology

FIGURE 4

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Bedrock

Bedrock of the region is composed of successional Middle Ordovician to Early Silurian Age carbonates and shales (Eyles, 2002). These rocks are undeformed and dip slightly to the south or southwest. Formations progressing from oldest to youngest follow the order: Shadow Lake Formation, Gull River Formation, Bobcaygeon Formation, Verulam Formation, Lindsay Formation, Blue Mountain Formation, Georgian Bay Formation, and lastly, Late Ordovician Queenston Formation (Earthfx, 2013). In the most western reaches of the region, early Silurian rocks of the Niagara Escarpment are found.

The underlying bedrock in the study area is mapped as the Georgian Bay Formation comprised of bluish grey shale with occasional bands of harder, greyish sandstone, siltstone and limestone (Chapman and Putnam, 1984). The bedrock is interpreted to be higher to the west and southwest of the study area (approximately 230 masl) with two interpreted bedrock valleys converging outside of the study area boundary in the vicinity of King Vaughan Road and Kipling Avenue to the southeast of Nobleton (**Figure 4**). The bedrock valley system is interpreted to slope to the south towards Lake Ontario (Earthfx, 2013).

2.3 Hydrogeology

2.3.1 Hydrostratigraphy

Hydrostratigraphic units can be subdivided into two distinct groups based on their capacity to permit groundwater movement: an aquifer or an aquitard. An aquifer is classically defined as a layer of soil permeable enough to permit a usable supply of water to be extracted. Conversely, an aquitard is a layer of soil that inhibits groundwater movement due to its low permeability.

A series of local hydrostratigraphic cross sections are shown in **Appendix B**. Groundwater flow is influenced by the following hydrostratigraphic units as described by Kassenaar and Wexler (2006) and summarized below:

Glaciolacustrine Deposits (Aquifer and Aquitard)

Extensive deposits of glaciolacustrine sand, silt and clay are the result of ice-marginal or ice-dammed lakes during the last recession of glacial ice. These deposits produce both aquifer and aquitard conditions based on deposition environments and resultant grain size distributions. The majority of these deposits are the result of Glacial Lake Iroquois and glacial lakes to follow to the south of the ORM and Glacial Lake Algonquin to the north of the ORM (Earthfx, 2013). Surficial glaciolacustrine deposits such as these can yield hydraulic conductivity values ranging from 10^{-4} m/s to 10^{-8} m/s depending on grain size distributions and the amount of weathering (Freeze and Cherry, 1979).

Low permeability fine-textured glaciolacustrine silt and clay deposits overlie the majority of the study area. These sediments act as a surficial aquitard and can locally combine with underlying till and channel deposits to limit groundwater recharge. Within the unit, it is expected that groundwater flows in a dominantly downwards direction towards more permeable aquifers. Small surficial sandy glaciolacustrine deposits, associated with higher energy near shore depositional environments, are found locally. This aquifer has the capacity to support groundwater discharge to streams and wetlands, however due to its limited extent and thickness is not a reliable source for groundwater supply.

Halton Till Aquitard

The Halton Till Aquitard is a silty clay to clayey silt till with hydraulic conductivities ranging from about 10^{-9} m/s to 10^{-5} m/s (Gerber and Howard, 2000). Differences in hydraulic conductivities result from spatial differences in matrix composition, interstitial lenses of sand, and degree of weathering. On a regional scale, the Halton Till Aquitard acts as a surficial aquitard, inhibiting local groundwater recharge and reducing the exposure of underlying aquifers to contamination (Sharpe et al., 1996). Isolated lenses of silt and fine sand within the till, however collect groundwater and often provide sufficient water for residential use. Within the till soils, groundwater flow is typically downwards towards the more permeable aquifer units. The water table is commonly high within the till due to the poorly drained nature of the soil.

The study area has extensive Halton Till deposits at surface, covering the entirety of the study area (**Figure 3**). In the study area, Halton Till will be difficult to differentiate from Newmarket Till, as there are limited ORAC deposits to stratigraphically separate the two tills. In combination with the Newmarket Till, the Halton Till Aquitard in the study area inhibits downward movement of water from the surface to underlying aquifers.

Oak Ridges Aquifer Complex

The Oak Ridges Aquifer Complex (ORAC) is a significant regional aquifer in Southern Ontario. The hydraulic conductivity of this aquifer is typically around $5x10^{-5}$ m/s (Gerber and Howard, 2000). It is the dominant domestic well source in the region and provides high quality water as short residence times prevent accumulation of dissolved solids. The Aquifer is typically unconfined with the exception of the southern ORM which is overlain by the Halton Till Aquitard.

The ORAC is not located at surface within the study area. The ORAC or equivalent unit depicted in **Appendix B** is interpreted as near-surface ORAC sediments. Near-surface ORAC sediments that extend into the study area form a shallow aquifers made up of Upper and Lower ORAC units. Interstadial sand deposits are typically thin and discontinuous, and occur between the Halton and Newmarket Till units. Due to the close proximity to the Oak Ridges Moraine, it is likely these deposits are hydraulically connected. Generally, only locally shallow dug wells obtain water from this aquifer as a result of its limited extent (MMM, 2007).

Regional Unconformity – Tunnel Channel Deposits

This unit has been identified as a regional unconformity at the top of the Newmarket Till (Sharpe, 1999), marked by a series of tunnel channels and valleys that have cut into or through the till. Within the Nobleton area, major tunnel channel deposits are found stratigraphically between the ORM and Newmarket Till (**Appendix B**). The tunnel channels are characterized by a fining-upward sequence of gravels, sands and silts deposited as meltwater energy waned (Earthfx, 2013). The lower portion of the channels are composed of sandy or gravelly sediments which act as aquifers, while the upper layers composed primarily of silts act as aquitards. Estimates of hydraulic conductivity resultant of calibrating the Core Model proposed by Kassenaar and Wexler (2006) are $5x10^{-7}$ m/s for silty aquitard structures higher up in the fining-upward sequence, and $1x10^{-4}$ m/s for aquifer deeper, sandy aquifer layers. The tunnel channels are important hydrogeological features that provide spatially discrete aquifers and/or promote connectivity between regional aquifers.

Within the Nobleton area, two major tunnel channel deposits are found stratigraphically between the ORM and Newmarket Till (**Appendix B**). One of these occupies approximately 1 km^2 of the most northeaster portion of the study area and the other approximately 400 m^2 in the most northwestern portion. The tunnel channels are important hydrogeological features to the area and are likely laterally hydraulically connected to the ORAC to the north.

Newmarket Till Aquitard

The Newmarket Till generally acts as a significant regional aquitard at the study area. The Newmarket Till is subdivided into units, which includes Upper Newmarket Till (UNT), Inter-Newmarket Sediments (INS), and the Lower Newmarket Till (LNT). The UNT and LNT units are considered the aquitard components being composed of over-consolidated Stony Till (silty sand to sandy silt matrix). The INS is considered an aquifer unit composed of silt to gravelly sands of glaciolacustrine or glaciofluvial origin. Hydraulic conductivity of this unit is approximately $8x10^{-5}$ (Gerber and Howard, 2000; Earthfx, 2013). The regional LNT and UNT aquitards have hydraulic conductivities of approximately $5x10^{-9}$ m/s and $1x10^{-8}$ m/s, respectively (Gerber and Howard, 2000; Earthfx, 2013).

The Newmarket Till acts as a significant aquitard in the study area. The INS is not found within the study area, leaving the combined UNT and LNT to act as a single aquitard. It acts to effectively separate the upper aquifer systems associated with the Oak Ridges Moraine from lower aquifers, including the Thorncliffe Formation and Sunnybrook Diamicton. Water flow within the dense till unit is typically in a downwards direction (Sharpe *et al.*, 1996).

Thorncliffe Aquifer

The Thorncliffe Aquifer is comprised of extensive stratified sands, and silty sand, and commonly silt and clay near the base of the deposit. The Thorncliffe Formation forms a thick extensive sand deposit underlying the Newmarket Till in the Study Area, and surrounding region. Hydraulic conductivity values typically range from $3x10^{-4}$ m/s to $1x10^{-8}$ m/s (Gerber and Howard, 2000). This aquifer is commonly used as a municipal groundwater source due to the overlying Newmarket Till Aquitard and low private well usage.

The Thorncliffe Formation forms a thick extensive sand deposit underlying the Newmarket Till in the Study Area. This unit is an important source of potable water to both private and municipal supplies in the Nobleton area.

Sunnybrook Aquitard

The clast-poor mud (silt and clay) deposits of the Sunnybrook forms a localized aquitard restricting flow from the Thorncliffe Formation to the Scarborough Formation. Sunnybrook in the study area is expected to be 10 to 20 m in thickness and has been estimated to have hydraulic conductivity values ranging from $3x10^{-7}$ m/s to $4x10^{-7}$ m/s (Gerber and Howard. 2000).

The clast-poor mud (silt and clay) deposits of the Sunnybrook Aquitard forms a localized aquitard restricting flow from the Thorncliffe Formation to the Scarborough Formation in the study area. Based on the 2013 stratigraphy model developed for the York Region Tier 3 Water Budget and Water Quantity Assessment (Earthfx, 2013), the Sunnybrook Aquitard is locally present within the study area.

Scarborough Aquifer

The aquifer is regionally extensive and is locally confined by the Sunnybrook Drift. The upward coarsening and increasing thickness of layers from clay-rich rhythmites to channelized cross-bedded sands promote greatest groundwater flow rates and storage within the upper layers of the unit (Kelly and Martini, 1986). Generally, the Scarborough Aquifer Complex is thin, however relatively thick deposits (60 – 80 m) are found in bedrock lows and valleys such as the Laurentian Valley and tributaries (MMM, 2007). Hydraulic conductivity in the aquifer has been estimated to be in the range of $2x10^{-5}$ m/s to $2x10^{-6}$ m/s (Gerber and Howard, 2000).

The Scarborough Formation aquifer forms the main potable water supply unit in the study area. The aquifer is regionally extensive and is locally confined by the Sunnybrook Drift. Within in the study area, the Scarborough Aquifer is more extensive than elsewhere in York Region, and can be up to 60 m thick within the bedrock valley located to the south-southwest and east of Nobleton running west to southeast and north to south. The three (3) municipal water supply wells for the village of Nobleton are installed in this formation approximately 100 mbgs.

2.3.2 Ministry of the Environment and Climate Change Water Well Records

Based on a search of the Ministry of the Environment and Climate Change (MOECC) Water Well Records (WWR) database, 150 WWRs were identified within a 500 m radius of the study area. Of the 150 wells identified, 80 were identified as being used for domestic water supply, 12 used for livestock or irrigation water supply, 5 used for commercial or industrial water supply, and 4 used for municipal water supply. The remaining 49 wells are either abandoned, test holes, observation wells or their use is not known (**Figure 5**). The majority of the domestic and commercial wells obtain water from the ORAC and Thorncliffe Aquifers.

2.3.3 Groundwater Elevation and Flow

The following describes groundwater levels and flow direction as presented within Earthfx (2013) for the ORAC/ Interstadial Aquifer (INS), Thorncliffe, and Scarborough aquifer units in the Nobleton area.

In Nobleton and the surrounding area, groundwater flow within the ORAC/ INS, Thorncliffe, and Scarborough aquifers is generally in a southerly direction (Earthfx, 2013). Groundwater flow within the shallow aquifers (ORAC/ INS) is strongly influenced by topography and the local watercourses such as the two main branches of the Humber River located to the east and southwest of Nobleton. Within the ORAC and INS aquifers, water level elevations range from approximately 260 masl within the higher surface elevations northwest of the community, to 225 masl by the Humber River valleys to the south of Nobleton. Static water levels in near-surface ORAC sediments that extend into the study area form an upper aquifer are interpreted at approximately 255 masl in the town centre (Earthfx, 2013). Static water levels in the shallow aquifer units are typically at a higher elevation than water levels in the underlying Thorncliffe Aquifer, particularly to the north of Nobleton in the direction of the moraine, indicating a downward hydraulic gradient or recharge conditions (Earthfx, 2013).

In the intermediate-deep Thorncliffe Aquifer, groundwater flow is generally to the south, with a moderate influence of the Humber River valley on the potentiometric surface (Earthfx, 2013). Static water levels range from approximately 250 masl in the northern portion of the study area to approximately 210 masl south of Nobleton. Static water level in the Thorncliffe Aquifer is interpreted at approximately 245 masl near the centre of the town (Earthfx, 2013).

In the deep Scarborough Aquifer, groundwater flow is to the south with very little evidence of flow convergence towards the Humber River system (Earthfx, 2013). Groundwater discharge from the Scarborough Aquifer does not appear to directly support base flow in local streams because of thick, fine-grained confining units which separate the shallow and deeper groundwater systems. Static water levels range from approximately 250 masl below the ORM to the north, to approximately 210 masl south of Nobleton. Static water level in the Scarborough Aquifer is interpreted at approximately 241 masl near the centre of the town based on data from Earthfx (2013) and York Region groundwater level monitoring data.

Within the study area, aquifers are confined by overlying Halton and Newmarket Till aquitard deposits, where present. Tunnel channel deposits have been identified in the Nobleton area (**Appendix B**) and suggest a potential hydraulic connection between aquifer units. In addition, the Sunnybrook Drift Aquitard may be discontinuous within the Nobleton area creating a hydraulic connection between the Thorncliffe and Scarborough aquifers.

Hydraulic gradients are generally downward across the study area from the ORAC/INS (where present in the areas north of the study area) downward into the Thorncliffe and then the Scarborough. However, upward gradients are interpreted in the low lying river valleys, such as the Humber River valley to the east of Nobleton where flowing wells have been recorded (MMM, 2007). The general downward gradient encourages groundwater recharge across the region, as infiltrating groundwater successively recharges the deeper aquifer units. Based on modeling work by Earthfx (2013), recharge rates range from 40 – 200 mm/yr in the Nobleton area.

2.4 Climate

The closest Environment Canada meteorological station is located at Toronto Pearson International Airport. The 1981 to 2010 climate normals indicate a mean annual temperature of 8.1 °C, with a range of monthly normals of -5.5 °C in January and 21.4 °C in August, and a total annual precipitation of 786 mm with a range of monthly normals between 47.7 mm in February and 78.1 mm in August (**Table 1**).

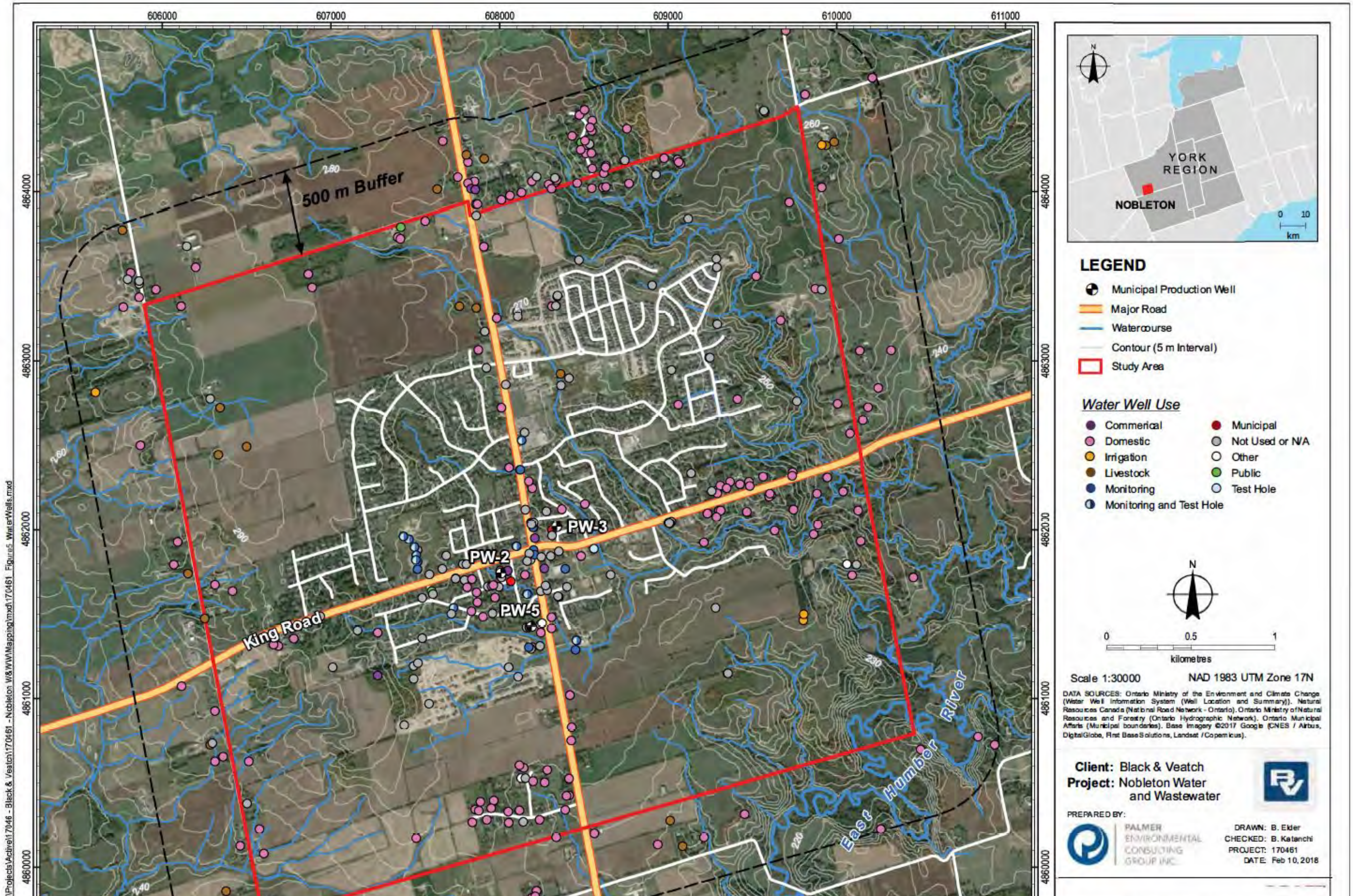
For the purposes of this study, a comparison of temperature and precipitation was made between the long-term climate normals and 2016. As shown in **Table 1**, all months in 2016 with the exception of April were warmer than the climate normals. The 2016 mean temperature was approximately 10.0 °C, with the monthly mean temperatures ranging from -3.6 °C in January to 24.3 °C in August.

With respect to precipitation, all months in 2016 with the exception of March and December produced lower total precipitation than the climate normal. The 2016 total precipitation was approximately 630.6 mm, with the monthly totals ranging from 26.4 mm in June to 80.0 mm in March. Of particular importance to this study is that the total precipitation during the early spring, summer and fall months of 2016 (May to Nov) was 329.4 mm, compared to the climate normal 510.2 mm. This represents 35% less precipitation over this time period. As will be discussed in Section 4 of this report, this reduced precipitation and higher than average temperatures led to increased water demand in 2016.

Table 1. 1981 – 2010 Climate Normals and 2016 Climate Data

Month	1981 to 2010 Climate Normal Mean Temperature (C)	1981 to 2010 Climate Normal Total Precipitation (mm)	2016 Mean Temperature (C)	2016 Total Precipitation (mm)
Jan	-5.5	51.8	-3.6	38.4
Feb	-4.6	47.7	-2.3	45.6
March	0.1	49.8	2.6	80.0
April	7.1	68.5	4.8	59.8
May	12.1	74.3	14.6	34.2
June	18.6	71.5	20.0	26.4
July	21.4	75.7	23.7	39.8
August	20.6	78.0	24.3	66.8
September	16.2	74.5	19.5	66.4
October	9.5	61.1	11.9	40.6
November	3.7	75.1	6.7	55.2
December	-2.2	57.9	-1.6	77.4
Average/ Total	8.1	785.8	10.0	630.6

Data obtained from Toronto INTL Airport (Government of Canada, 2018).



Water Wells

FIGURE 5

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3. Source Water Protection

Under the Clean Water Act, 2006 (CWA), all sources of drinking water must be assessed with respect to vulnerability. These assessments were completed in 2015 for Nobleton through the "Approved Assessment Report: Toronto and Region Source Protection Area, Water Budget and Stress Assessment". The Technical Rules (2017) require that the Source Protection Committees (SPC) identify the types of vulnerable areas within each Source Protection Area (SPA). These vulnerable areas include: Wellhead Protection Areas (WHPAs), Highly Vulnerable Aquifers (HVAs) and Significant Groundwater Recharge areas (SGRAs).

3.1 Wellhead Protection Areas (WHPAs)

Wellhead Protection Areas (WHPAs) are zones around municipal drinking water wells which are applied to protect the community's source water. These zones are the basis for a community's Source Protection Plan, which provides guidelines for monitoring and regulation of land uses near the well field.

Each WHPA is delineated based on groundwater flow calculations and pumping rates and is based on a mathematical model. WHPAs assume a specified time of travel from the outer edge of the zone to the well intake. The size and shape of each WHPA depended on the pumping rate of the well and the properties of the aquifer providing water to the well. WHPAs are subdivided based on distance or transit time boundaries. WHPA-A, WHPA-B, WHPA-C and WHPA-D boundaries are 100 m, less than or equal to 2 years, less than or equal to 5 years, and less than or equal to 25 years, respectively.

As shown in **Figure 6**, a large portion of the study area is located within the Wellhead Protection Area (WHPA) A, B, C and D, as well as WHPA-Q (Recharge Management Area). The majority of the northern portion of the study area is within a WHPA-A, B, C or D. WHPA-A is illustrated around each municipal pumping well. WHPA-B,C and D are also shown to extend beyond the northern boundary of the study area. **Table 2** presents a summary of the WHPA Zones for each production well based on the location of the York Region groundwater monitoring well network. The location of the groundwater monitoring wells is presented on **Figure 12**.

Table 2. WHPA Summary

Well	WHPA Zone (corresponding production wells)
MW-1S	5 Year (All production wells)
MW-1D	5 Year (All production wells)
MW-2S	100 m (PW-2)
MW-2D	100 m (PW-2)

Well	WHPA Zone (corresponding production wells)
MW-3S	2 Year (All production wells)
MW-3D	2 Year (All production wells)
MW-4S	100 m (PW-5)
MW-4I	100 m (PW-5)
MW-4D	100 m (PW-5)
MW-5	100 m (PW-5)
MW-6	100 m (PW-5)
MW-8S	25 Year (All production wells)
MW-8D	25 Year (All production wells)

(from York Region, 2016 Water Resource Annual Monitoring Report)

The portion of the study area that is located within the WHPA-Q, is subject to the recharge management policy. Hydrogeological assessment and water balance may be required to ensure infiltration volumes at the study area are maintained. The area of high permeability glaciolacustrine and glaciofluvial sands identified as Significant Groundwater Recharge Area (SGRA) classes to 2 to 6.

Based on the report "Approved Assessment Report: Toronto and Region Source Protection Area, Water Budget and Stress Assessment" completed in 2015, it was concluded by York Region staff, with the concurrence of the peer reviewers, no transport pathway adjustments were made for the three (3) Nobleton productions wells. The resultant WHPA, as part of the uncertainty assessment, shows the uncertainty in delineation of WHPA-A, WHPA-B, WHPA-C and WHPA-D and scoring of vulnerability within each are considered low for all three production wells.

3.2 Highly Vulnerable Aquifers (HVAs)

A highly vulnerable aquifer (HVA) is identified in the Ontario Clean Water Act, 2006 as highly vulnerable to contamination based on factors such proximity to the ground surface, the thickness and hydraulic characteristics of the overlying deposits (i.e., aquitards, aquifers), and the radial proximity to aquifers/aquitards sharing depths below ground surface.

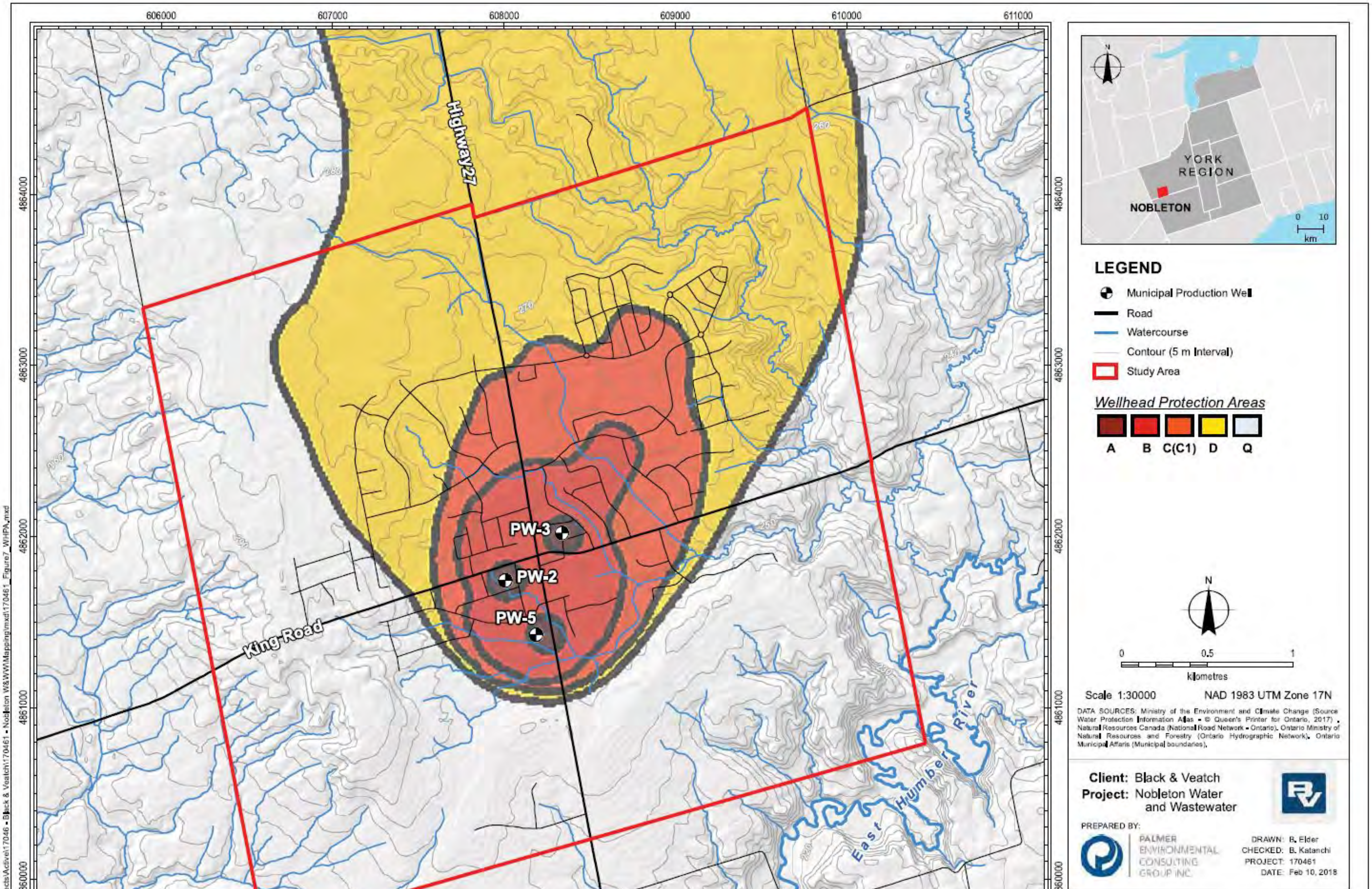
As shown in **Figure 7**, two (2) significant HVAs are located within the study area; the first in close proximity to the city centre, slightly east of Highway 27 and King Road, and the second in an area on the eastern portion of the study area extending from the north to south boundary coinciding with surficial glaciolacustrine and alluvial deposits..

The majority of the surficial geology of the study area consists of either low permeability glaciolacustrine silty and clay, or low permeability sandy silt till aquitard materials. The regionally significant Thorncliffe and Scarborough Aquifers are situated in this area are confined by the overlying till and glaciolacustrine units. While the Scarborough Aquifer is important for municipal groundwater supply, the Halton and Newmarket tills act to inhibit vertical recharge to the aquifer. The primary recharge area for this aquifer is located north of the study area, where high permeability Oak Ridges Moraine deposits are present at surface.

3.3 Significant Groundwater Recharge Areas (SGRAs)

Infiltration is the term used to describe the volume of water that enters the subsurface from a surface source, whereas recharge is the term used to describe downward flowing groundwater which reaches an underlying aquifer. Infiltration aside, precipitation that reaches the ground surface is either lost to evaporation or runs off the surface directly into streams, other water bodies (i.e. lakes, ponds), or storm sewers. The remainder infiltrates into the ground, a portion of which may be transported to an underlying aquifer to act as recharge.

Recharge areas are important because they replenish aquifers. As mentioned, the ORM (where exposed at surface) exhibits the greatest rate of groundwater recharge within the vicinity of the study area. Nearly all of the precipitation infiltrates into the crest area of the ORM due to the high permeabilities of these surficial deposits, a large portion of this infiltrated precipitation acts as recharge to the ORAC. Piezometer nests installed in the ORAC confirm downward groundwater flow directions and a deep water table (e.g. Singer, 1977). Minor groundwater recharge also occurs in areas of the South Slope that are underlain by ORAC sediments and where the Halton Till is thin. In the areas of thicker Halton Till and/or Newmarket Till, runoff exceeds recharge due to these low permeability deposits.



Wellhead Protection Areas

Figure 6

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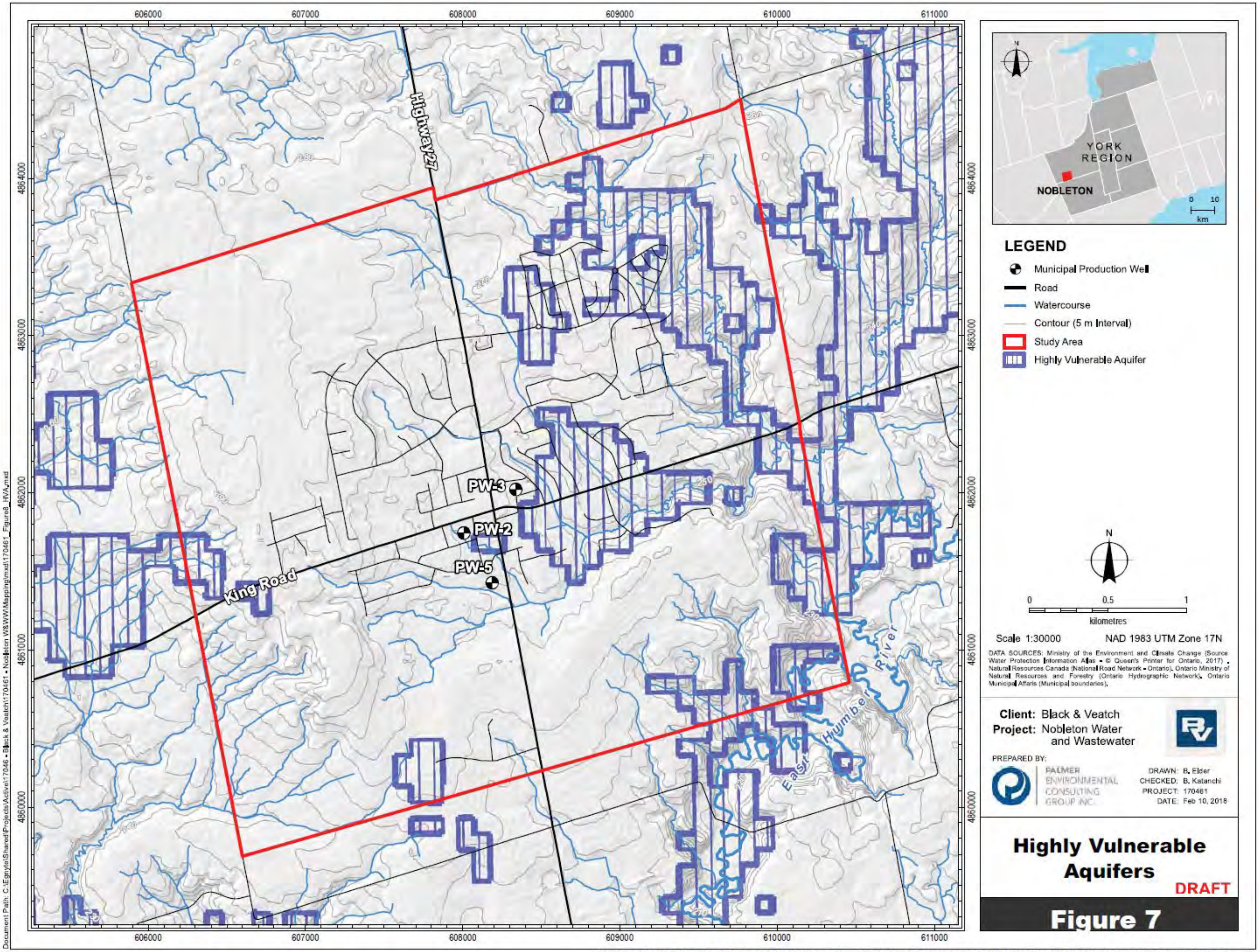

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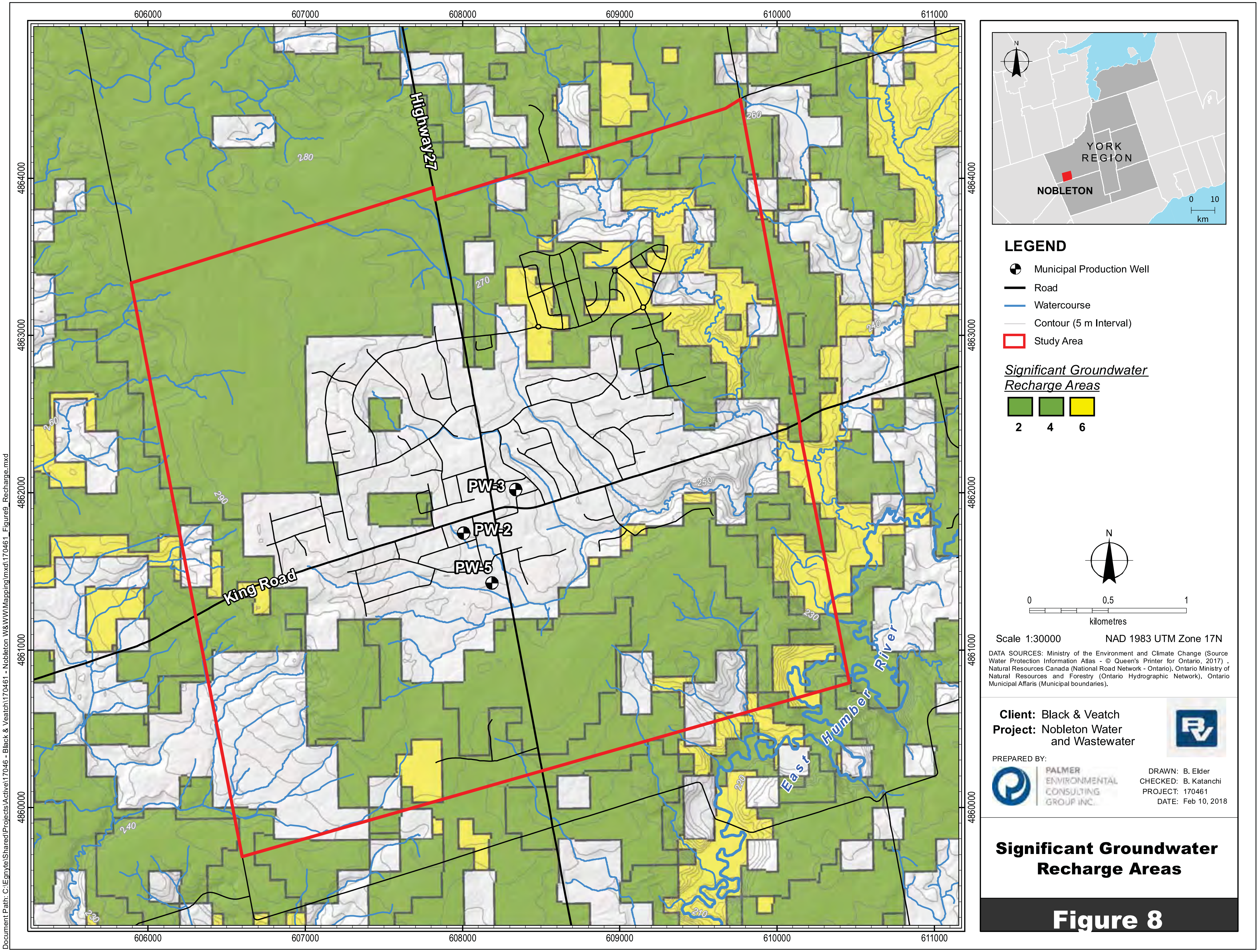

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As shown in **Figure 8**, the majority of the study area outside of the city centre is classified as being a significant groundwater recharge area (ranging from groundwater recharge zones 2 to 6). These areas generally have a relatively high surficial permeability. Within the study area, groundwater infiltration as a percentage of total precipitation ranges from 13 – 24 % (TRCA, 2015). The majority of the study area is classified as having a SGRA vulnerability score of 2 or 0, with a small fraction of the east and northeast areas having a score of 6. Only SGRAs with vulnerability scores of 6 require recharge management policies. The SGRAs with a score of 6 falling within the WHPAs fall under the same management policies mentioned in Section 3.1. SGRAs with a score of 6 falling outside the WHPAs, will identifical management policies to those within the WHPAs.

3.4 Provincially Significant Wetlands (PSWs)

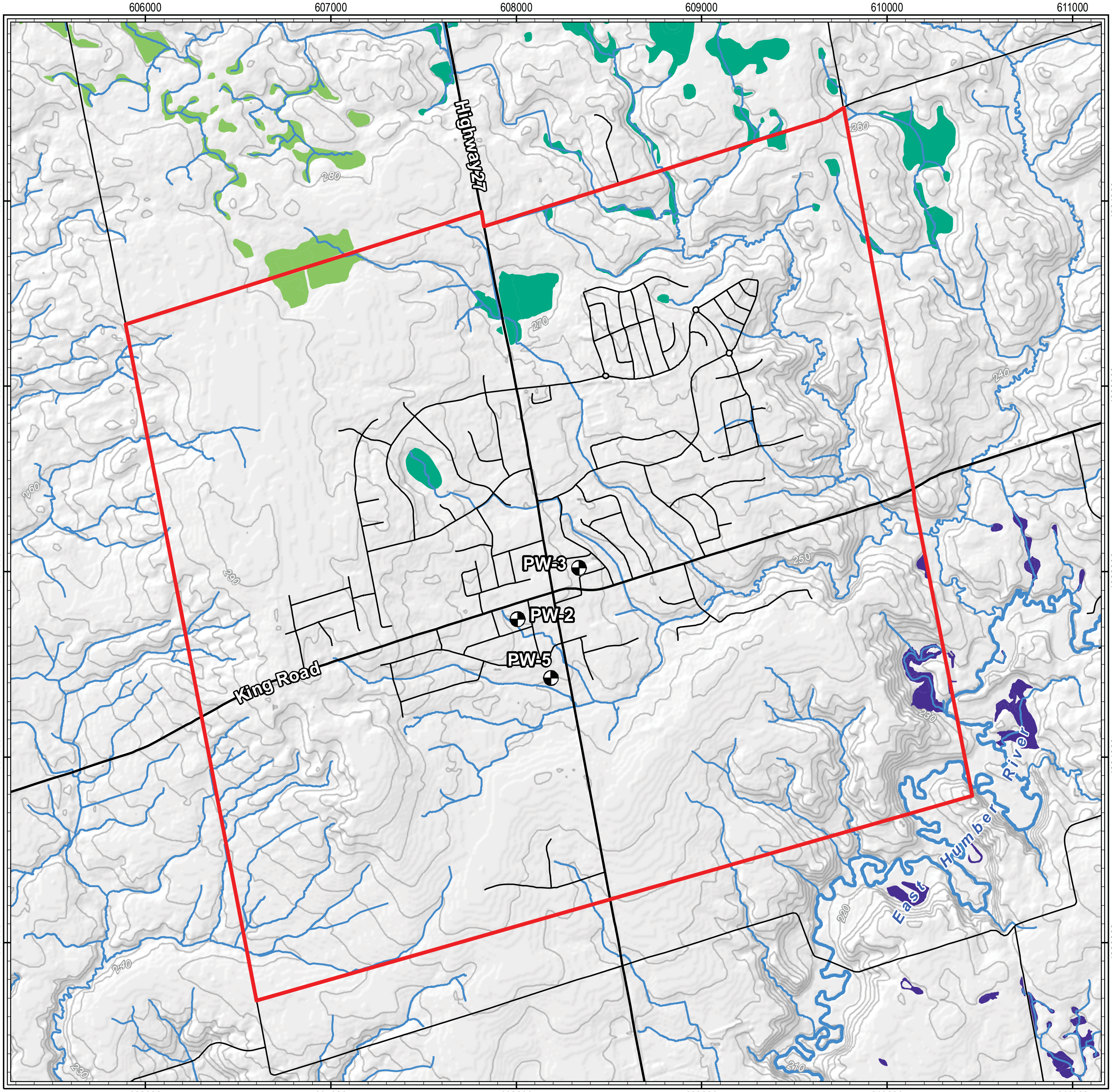
Provincially Significant Wetlands (PSWs) are those areas identified by the province as being the most important to ecological and hydrological health. They are determined by a ranking system known as the Ontario Wetland Evaluation System (OWES). This Ministry of Natural Resources and Forestry (MNRF) framework provides a standardized method of assessing wetland functions and societal values, which enables the province to rank wetlands systematically. A wetland that has been evaluated using the criteria outlined in the OWES is known as an evaluated wetland. The PSWs identified within the study area are shown on **Figure 9**.

Three (3) PSWs are identified within the study area: The Nobleton, Black Duck and East Humber River. The identified PSWs are located at various portions of the study area. The Nobleton PSW is identified in the north western portion of the study area, the Black Duck PSW is in the north central portion and the East Humber River PSW is located in the south east portion of the study area.

3.5 Areas of Natural and Scientific Interest (ANSI)

Areas of Natural and Scientific Interest (ANSI) are areas of land and/or water containing natural landscapes or features which have been identified as having life science or earth science (or both) values related to natural heritage protection, scientific study or education. ANSIs vary in their type and level of significance. Provincially Significant ANSIs are sites selected on a systematic basis (using the above selection criteria) and contribute to the representation of the natural features and landscapes of Ontario. Life Science ANSIs contain landform/vegetation features of a particular ecodistrict. Earth Science ANSIs contain earth science features for an environmental theme.

As shown in **Figure 10**, no Provincially Significant ANSIs are identified within the study area however, a candidate Life Science ANSI, is identified in the north-western portion of the study area. Candidate ANSIs are areas of natural and scientific interest that have been identified and recommended for protection by the Ministry of Natural Resources and Forestry (MNRF) or other sources but have not been formally confirmed through the confirmation procedure. The MNRF confirms whether the ANSI is provincially, regionally, or locally significant. If the candidate ANSIs is identified as being significant this will need to be taken into consideration if any future development were to occur at or near that location.



LEGEND

- Municipal Production Well
- Road
- Watercourse
- Contour (5 m Interval)
- Study Area

Provincially Significant Wetland Complex

- Nobleton
- Black Duck
- East Humber River

0 0.5 1
kilometres

Scale 1:30000

NAD 1983 UTM Zone 17N

DATA SOURCES: Ontario Ministry of Natural Resources and Forestry (Wetlands, Ontario Hydrographic Network). Natural Resources Canada (National Road Network - Ontario). Ontario Municipal Affaris (Municipal boundaries).

Client: Black & Veatch
Project: Nobleton Water and Wastewater

PREPARED BY:
PALMER ENVIRONMENTAL CONSULTING GROUP INC.

DRAWN: B. Elder
CHECKED: B. Katanchi
PROJECT: 170461
DATE: Feb 10, 2018

Provincially Significant Wetlands

DRAFT

Figure 9

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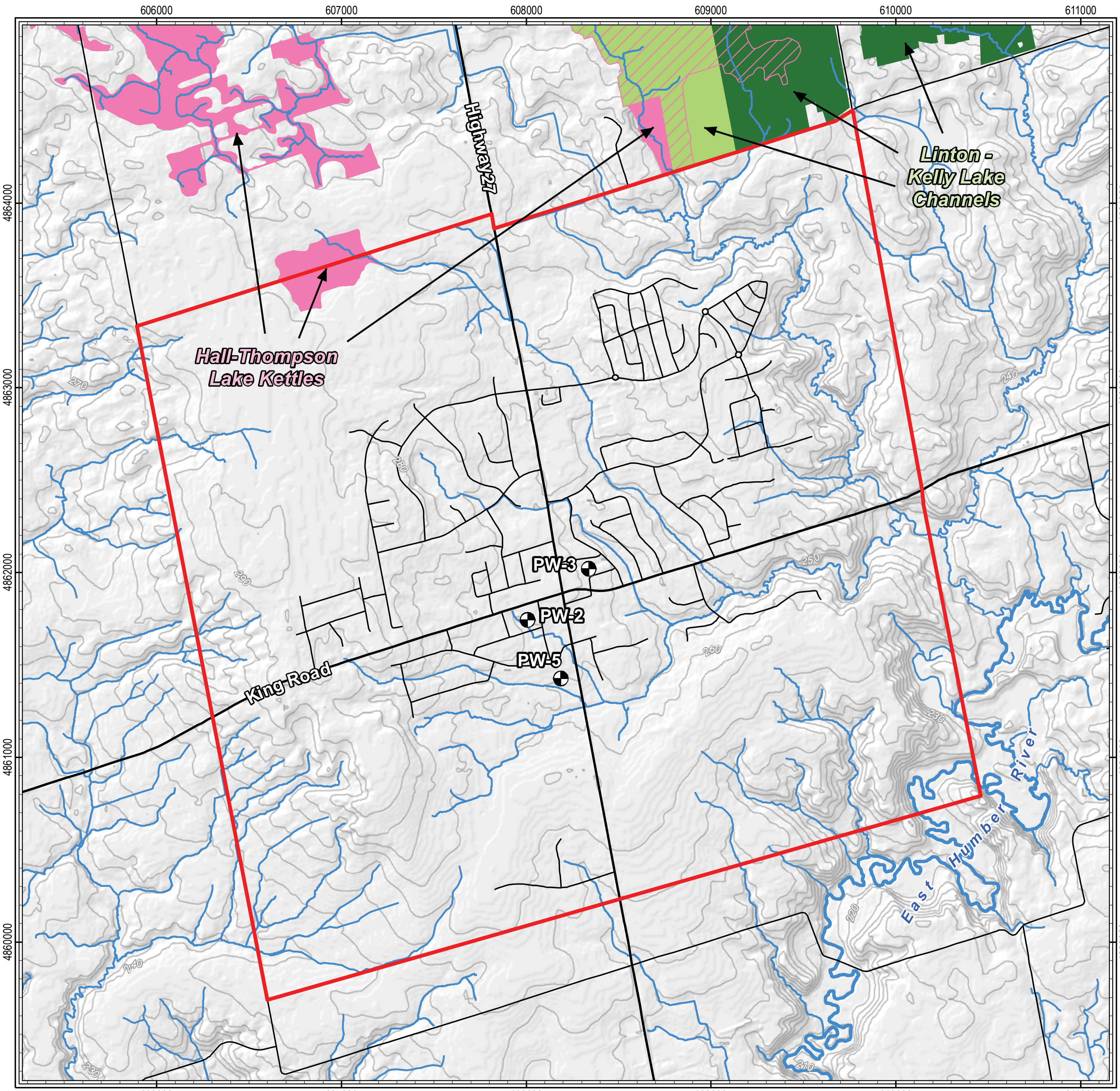

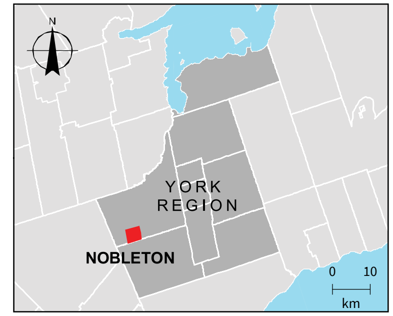

LEGEND

- Municipal Production Well
- Road
- Watercourse
- Contour (5 m Interval)
- Study Area

Areas of Natural and Scientific Interest

- ANSI, Earth Science
- Candiate ANSI, Earth Science
- Candidate ANSI, Life Science
- Candidate ANSI, Life Science (Overlap)

N

0 0.5 1
kilometres

Scale 1:30000 NAD 1983 UTM Zone 17N

DATA SOURCES: Ontario Ministry of Natural Resources and Forestry (ANSI, Ontario Hydrographic Network), Natural Resources Canada (National Road Network - Ontario), Ontario Municipal Affaris (Municipal boundaries).

Client: Black & Veatch
Project: Nobleton Water and Wastewater

PREPARED BY:
PALMER ENVIRONMENTAL CONSULTING GROUP INC.

DRAWN: B. Elder
CHECKED: B. Katanchi
PROJECT: 170461
DATE: Feb 10, 2018

Areas of Natural and Scientific Interest

Figure 10

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4. Nobleton Groundwater Supply, Groundwater Monitoring and Future Demand

4.1 Groundwater Supply Well Summary

4.1.1 Nobleton Municipal Production Wells

Nobleton receives its drinking water from three (3) groundwater production wells under MOECC PTTW# 0550-9PPRJ9 (PW-2, PW-3, PW-5), which are managed by York Region. These wells service a current population of approximately 5,500 (York Region Planning Department, 2016). A summary of the production wells is provided in **Table 3**. The PTTW for the production wells was issued on October 14, 2014 and is set to expire on December 31, 2019.

Table 3. Nobleton Water Supply Permits to Take Water

Permit Number	Nobleton Production Supply Well Number	Aquifer Unit	Date Installed	Diameter (m)	Maximum Permitted Water Taking Rate (L/day)
0550-9PPRJ9	PW-2	Scarborough Formation	1961	0.32	1,964,000
	PW-3	Scarborough Formation	1968	0.32	2,496,000
	PW-5	Scarborough Formation	2012	0.32	2,496,000
	PTTW Combined Pumping Rate (L/day)				4,460,000

All three (3) production wells are completed within the Scarborough Aquifer Formation. Production Wells PW-2 and PW-3 were installed in 1961 and 1968, respectively, while production well PW-5 was installed in 2012 and brought into operation in 2015. Aquifer transmissivity was calculated at PW-3 by Jagger Hims Ltd (1997) to be 550 m^2/day, and MMM (2012) calculated aquifer transmissivity at PW-5 to be 790 m^2/day. Jager Hims (1997) also calculated aquifer storativity at PW-3 to be 0.0004.

Production Well PW-2 located near 22 Faris Avenue, Nobleton, Ontario, is a 0.32 m diameter well, drilled in 1961, and is screened from 104.5 to 110.5 m depth within a deposit of sand and gravel. The screen consists of 6.0 m of stainless steel, wire-wrapped screen. During well testing, the well was pumped for 24 hours at a rate of 2,488 m^3/day, drawing down the water level by 9.3 m. From this, specific capacity was estimated at 267 m^3/day/m. At the time of well development completion, the static water level was reported at 18.0 m below grade (MMM, 2007).

Production Well PW-3 located near 14 Royal Avenue, Nobleton, Ontario, was completed in 1968 and is also a 0.32 m diameter well, screened in predominantly fine to medium sand, and into a gravelly zone at the base of the screen. The stainless steel, wire-wrapped screen is 6.95 m length. During well testing, the well was pumped for 72 hours at a rate of 2,292 m^3/day and drew down by 11.3 m. From this testing the specific capacity was estimated at 203 m^3/day/m. Static water level at the time of well development completion was 16.6 m below grade, which is the same as reported by Jagger Himms Ltd. in 1997. The water level at the well after 89 hours pumping was measured at approximately 33.4 m below grade. The water level in this well at one hour after restarting pumping was measured at 32.7 m below grade (MMM, 2007).

Production Well PW-5 located west of Highway 27 and south of Ellis Avenue, in the south end of Nobleton, and was completed in 2012 and was commissioned in 2015. It also is a 0.32 m diameter well, screened in a sand and gravel unit with the Scarborough formation. The static water level at the time of completion was 20.49 mbgs (MMM, 2012). The total open slot screen length was 3.05 m and the screen was designed to have a calculated capacity of 1980 L/min (33 L/s). Testing completed by MMM (2012) demonstrated a specific capacity of approximately 930 m^3/day/m (10.8 L/sec/m) indicating a relatively high efficiency.

4.1.2 Groundwater Quality

Groundwater quality of the production wells are regularly tested for compliance of the under the Safe Drinking Water Act (2002, S.O. 2002, c. 32). The raw and treated water results from the production wells were reviewed as part of the “Class Environmental Assessment and Water Resources Exploration for Water Supply and Storage in the Community of Nobleton” report completed by MMM in 2007. In addition, this report reviewed recent data as reported by the York Region Drinking Water Report dated 2016.

Based on the York Region Drinking Water Report 2016, iron, manganese and hardness levels are naturally elevated, which is common in deep aquifers across York Region. These results are summarized in **Table 4**. Regular raw water samples are analyzed to monitor the health of the aquifer. Water Treatment and Supply Disinfection is maintained with chlorine. Water from PW-2 and PW-5 are disinfected with chlorine gas. Water from PW-3 is disinfected with sodium hypochlorite. Sodium silicate is added at all wells to manage iron and manganese in the distribution system.

In addition to routine water testing and facility inspections by operators, online analyzers continuously monitor the treatment and delivery processes. These analyzers trigger alarms and automatically shut down and lockout pumps to notify operators when immediate attention is needed on site (York Region Drinking Water Report, 2016).

Table 4. Water Chemistry Summary

Treated Water Parameters	Hardness	Sodium	Fluoride	Chlorine	E. Coli	Total Coliforms
Average Results	254 mg/L	20 mg/L	0.13 mg/L	1.63 mg/L	Not Detected	Not Detected

Source: York Region Drinking Water Report 2016

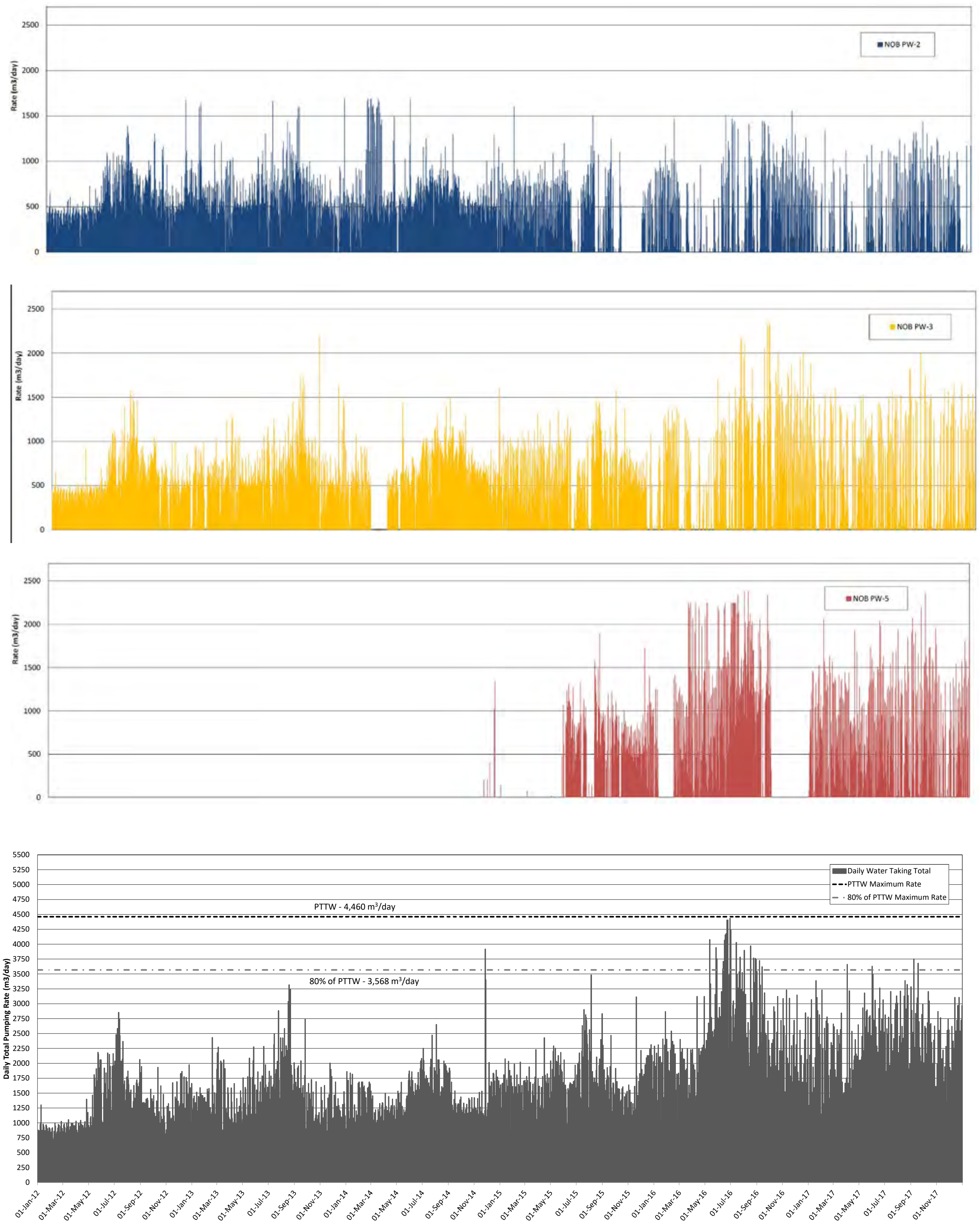
4.1.3 Current and Future Water Demand

The current water supply system supports a population of approximately 5,500 persons in Nobleton. The permitted capacity under PTTW 0550-9PPRJ9 is 4,460 m^3/day. The firm capacity (i.e., the water supply capacity with one well out-of-service) is also 4,460 m^3/day, with a redundancy of 2,496 m^3/day. Based on future projected population forecasts, Nobleton will grow to a population of 10,800 by 2031. This represents a 96% increase in population from the current population. Without considering water use reductions through conservation or other municipally led programs, it has been conservatively assumed that water demand will also increase by 96% by 2031.

Based on the report "Installation and Testing of Municipal Well NOB-PW5" (MMM, 2012) report and as shown in **Table 3**, the sum of the maximum permitted extraction rates of each pumping well is not equal to the total water system maximum extraction rate due to expected drawdown interferences between pumping wells. This is due to measured drawdown interference effects between the wells; however, the cumulative effect and magnitude of the combined drawdown has not been studied in detail.

Figure 11 presents the total daily water taking rate for each production well between January 2012 and December 2017 as provided by York Region. Between January 2012 and May 2015, the average combined production rate from PW-2 and PW-3 was 1,260 m^3/day. In May 2015, PW-5 was brought on line, and between May 2015 and December 2017, when PW-5 was also pumping, the average daily production rate increased to 1,653 m^3/day. The maximum daily water taking for each well is summarized in **Table 5**.

The maximum pumping rate for each well occurred during 2016, which was a significantly hotter and drier year than average (see **Table 1** for a climate summary), and also corresponded to increased population growth and subsequent water demand. The maximum daily water taking rate at PW-2, PW-3, and PW-5 were 1,554 m^3/day, 2,326 m^3/day, and 2,375 m^3/day, respectively



PALMER ENVIRONMENTAL CONSULTING GROUP INC.

Date: February 2018

Drawn: MG

Project: 17043

Checked: JC

Figure 11

Total Daily Water Taking Rate: PW-2, PW-3, PW-5 and Combined

For the purposes of this assessment, the production wells are considered to be operating at peak capacity if withdrawal is within 80% of permitted capacity. Between January 2012 and December 2017, PW-3 pumped at peak capacity on 8 days, and PW-5 pumped at peak capacity on 32 days. The majority of these days occurred in 2016. PW-2 did not pump at peak capacity between 2012 and 2017.

The total combined water taking rate is presented in **Figure11**. While the PTTW rate was not exceeded between 2012 and 2017, on 22 days the combined pumping was more than 80% of the permitted capacity, with the majority of these days occurring between May and November 2016. On July 5, 2016, the combined water taking rate was 99% of the PTTW daily withdrawal limit.

Table 5. Permitted, Average and Maximum Water Taking (Jan 2012 – Dec 2017)

Location	**Permitted Daily Water Taking (L/day)**	**Average Daily Water Taking: Jan 2012 – May 2015 (L/day)**	**Average Daily Water Taking: May 2015 – Jan 2017 (L/day)**	**Maximum Daily Water Taking (L/day)**	**Number of Days Operating at Peak Capacity (*80% of Permitted Capacity*) (Annual)**
PW-2	1,964,000	628,828	1,024,313	1,553,875 (Nov 8, 2016)	0
PW-3	2,496,000	626,432	576,500	2,326,375 (Aug 30, 2016)	8
PW-5	2,496,000	-	901,750	2,374,469 (July 29, 2016)	32
Combined	4,460,000	1,259,812	1,653,019	4,433,100 (July 5, 2016)	22

Source: York Region Drinking Water Report, 2016 and Data Provided by YR (2017)

An assessment of the *average daily* water taking rates suggests that a 96% increase in population and subsequent average daily water demand from 1,653 m^3/day to 3,240 m^3/day can be accommodated under the current PTTW (and firm capacity) and with the current number of production wells. However, it is clear that additional permitted groundwater capacity will be required to accommodate peak demand for even a moderate population growth especially when taking into consideration the potential for increasingly dry and hot summers such as experienced in 2016. Considering that the population of Nobleton is planned to grow from a current population of 5,500 to a population of 10,800 by 2031, the permitted groundwater capacity and firm groundwater capacity will need to be approximately 8,689 m^3/day or a 96% increase from current capacity.

Without taking into consideration interference effects, the potential combined water taking rate from the three existing production wells is 6,956 m^3/day. Therefore, at least 1,733 m^3/day of additional firm capacity is required to meet peak demand. This could be achieved through increasing the permitted capacity of one or more of the existing production wells or through the drilling and installation of a new production well. It's important to note that this additional capacity does not consider a reduction of existing well capacity due to interference effects or limitations to pumping based on potential impacts to existing water users or the natural environment. These will need to be determined though a hydrogeological study.

This analysis also does not take into consideration the need for redundancy in the municipal water supply system. The water supply system for Nobleton should be sufficient such that the highest capacity well can be off-line, and the community can still meet its peak water supply demand. This would require approximately 2,500 m^3/day of additional serviced capacity for the town beyond the approximately 8,689 m^3/day of estimated required firm capacity. Therefore, the existing serviced capacity of 4,460 m^3/day would need to be increased to approximately 11,189 m^3/day to meet future demand and redundancy requirements.

4.2 Groundwater Level and Drawdown

4.2.1 Monitoring Well Network

York Region manages a series of shallow and deep groundwater monitoring wells in Nobleton targeting the Oak Ridges Aquifer Complex (ORAC), the Thorncliffe Aquifer, and the Scarborough Aquifer formations. The location of these wells is shown on **Figure 12**.

Table 6 summarizes the depth, screened interval and interpreted aquifer unit for each monitoring well and production well. In general, the shallow wells are screened within the Upper or Lower ORAC and the deep wells are screened in the Scarborough Formation. Well MW3s is completed in the Thorncliffe Aquifer Formation. York Region has provided daily groundwater elevation data collected between January 1, 2012 and December 31, 2017 to be used as part of this study.

Table 6. York Region Monitoring Well Summary

Well	Screened Interval (masl)	Interpreted Aquifer Formation (YR, 2017)	Shallow or Deep Aquifer
PW-2	155.47-161.46	Scarborough	Deep
PW-3	172.58-179.29	Scarborough	Deep
PW-5	159.26-163.83	Scarborough	Deep
NOB MW-1D	232.45-235.50	Scarborough	Shallow
NOB MW-1S	162.29-165.33	Lower ORAC	Deep
NOB MW-2D	225.20-228.21	Scarborough	Shallow
NOB MW-2S	156.77-157.99	Lower ORAC	Deep

Well	Screened Interval (masl)	Interpreted Aquifer Formation (YR, 2017)	Shallow or Deep Aquifer
NOB MW-3D	231.53-234.58	Thorncliffe	Shallow
NOB MW-3S	172.70-175.73	Lower ORAC	Deep
NOB MW-4D	239.51-240.69	Scarborough	Shallow
NOB MW-4I	219.61-222.60	Lower ORAC	Shallow
NOB MW-4S	158.43-161.43	Upper ORAC	Deep
NOB MW-5	158.83-163.63	Scarborough	Deep
NOB MW-6	159.57-165.968	Scarborough	Deep
NOB MW-8D	235.37-238.42	Scarborough	Shallow
NOB MW -8S	172.23-175.28	Lower ORAC	Deep

4.2.2 Production Well Drawdown and Interference

Groundwater elevation data for PW-2, PW-3, and PW-5 was provided by York Region. **Figure 13** presents groundwater elevation along side the total daily pumping rates for each production well and a total combined pumping rate. As expected, groundwater elevation in the production wells is directly related to the total daily pumping rate. As the Scarborough Formation is a deep confined aquifer, drawdown effects from seasonal precipitation trends are not expected to be significant relative to pumping effects.

Between January 2012 and May 2015 when both PW-2 and PW-3 were pumping, the groundwater elevation at PW-2 ranged from approximately 243 masl to 234 masl, a difference of 9 m (**Figure 13**). No groundwater data from PW-3 was provided by York Region prior to 2016 for this assessment. In February 2014, PW-3 was shut down for maintenance, and only PW-2 was pumping. During this time, the water level at PW-2 ranged from approximately 241.5 masl to 239.5 masl or 2 m of drawdown. When PW-3 was brought back on line in March 2014, the water level in PW-2 gradually declined to an elevation of approximately 236 masl by August 2014 (a drawdown of 5.5 m). This result suggests a well interference of approximately 5.5 m between PW-2 and PW-3, which is consistent with MMM (2012).

PW-5 started regular production on May 15, 2015. A drawdown from approximately 241.5 to 236.25 masl or 5.25 m was observed at PW-5 after approximately 7 days of pumping, which is consistent with the hydraulic testing completed by MMM (2012). Interestingly, a drawdown from approximately 239 to 236.25 masl was also observed in PW-2, suggesting approximately 2.75 m of interference.

As is summarized in **Table 7** below, and is apparent from **Figure 13**, significant drawdown outside of the historical trends was measured in 2016 in all three production wells. Between mid February 2016 and mid April 2016, the majority of the groundwater production in Nobleton was from the newly installed PW-5. Below average groundwater taking from PW-2 and PW-3 occurred over this period. The water level elevation in PW-2 declined from approximately 239 to 233.5 masl (5.5 m) and the water level elevation in

PW-3 declined from approximately 241 to 240 masl (1 m). This suggests well interference of 5.5 m between PW-5 and PW-2 and 1 m of interference between PW-5 and PW-3.

Starting in mid-April 2016 and continuing to the end of September 2016, groundwater demand in Nobleton significantly increased due to limited precipitation (described in **Table 1**) and population growth. The average demand over this time period was 2,336 m^3/day, with a peak demand of 4,433 m^3/day occurring on July 5, 2016. All production wells were pumping at higher than average rates during this time period and on some days all three production wells were used (although not at the same time as per PTTW requirements). As presented on **Table 7**, over this time period a drawdown of 9.69 m, 14.72 m and 9.85 m were measured at PW-2, PW-3 and PW-5, respectively. This represents approximately double the 2012 to 2015 average pumping rate and drawdown and provides an estimate of the combined drawdown and well interference effects.

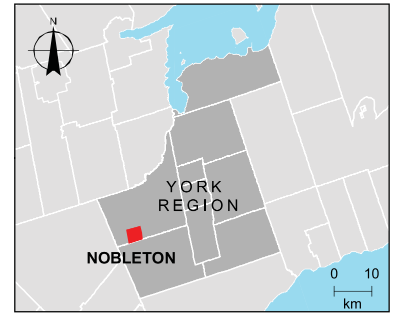
In September 2016, pumping at PW-5 stops and does not resume until mid-December 2016. A steady water level increase is observed over this period in PW-2 from an elevation of approximately 230.5 to 238.5 masl (8 m) and in PW-3 from 235 to 241 masl (6 m). This increase in groundwater elevation is consistent with the estimated interference effects from the drawdown as described above.

4.2.3 Monitoring Well Drawdown

The groundwater elevation for each monitoring well is plotted on **Figures 14 to 20** alongside the production well water elevations and pumping rate. The water level in each monitoring well as has also been sorted by aquifer unit (ORAC, Thorncliffe, and Scarborough), and are presented on **Figures 21 to 23**. **Table 5** provides a summary of the screened aquifer unit for each monitoring and production well.

As described in the York Region, Water Resource Annual Monitoring Report (2016) and confirmed as part of this study, over the last five years water levels in the deep aquifer have declined by approximately four meters, coinciding with the increase in groundwater pumping (**Figures 13** and **21**). Water level trends in the Thorncliffe and ORAC aquifers resemble the Scarborough aquifer trend and have declined by between approximately four and two meters over the last five years, respectively (**Figures 22** and **23**).

Monitoring wells screened in the Scarborough Formation (MW-1D, 2D, 4D, 5, 6, and 8D) respond to pumping at PW-2, PW-3 and PW-5 (**Figure 21**). Drawdown in these wells is directly related to the combined pumping rate although PW-5 appears to have the largest effect. MW-3D, which is screened in the Thorncliffe Formation, also responds to production well pumping indicating a strong hydraulic connection between the Scarborough and Thorncliffe formations (**Figure 22**). This is potentially the result



LEGEND

- Road
- Watercourse
- Contour (5 m Interval)

WELL INFORMATION:

- Municipal Production Well
- Monitoring Well

Colour denotes **AQUIFER COMPLEX**

- Scarborough
- Lower ORAC
- Upper ORAC
- Thorncliffe

N

0 100 200 300

Meters

Scale 1:10000 NAD 1983 UTM Zone 17N

DATA SOURCES: Ontario Ministry of the Environment and Climate Change (Water Well Information System (Well Location and Summary)). Natural Resources Canada (National Road Network - Ontario). Ontario Ministry of Natural Resources and Forestry (Ontario Hydrographic Network). Ontario Municipal Affaris (Municipal boundaries). Imagery (2015) Source: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

Client: Black & Veatch
Project: Nobleton Water and Wastewater

PREPARED BY:

PALMER ENVIRONMENTAL CONSULTING GROUP INC.

DRAWN: B. Elder
CHECKED: J. Cole
PROJECT: 170461
DATE: Feb 15, 2018

Groundwater Monitoring Wells

FIGURE 12

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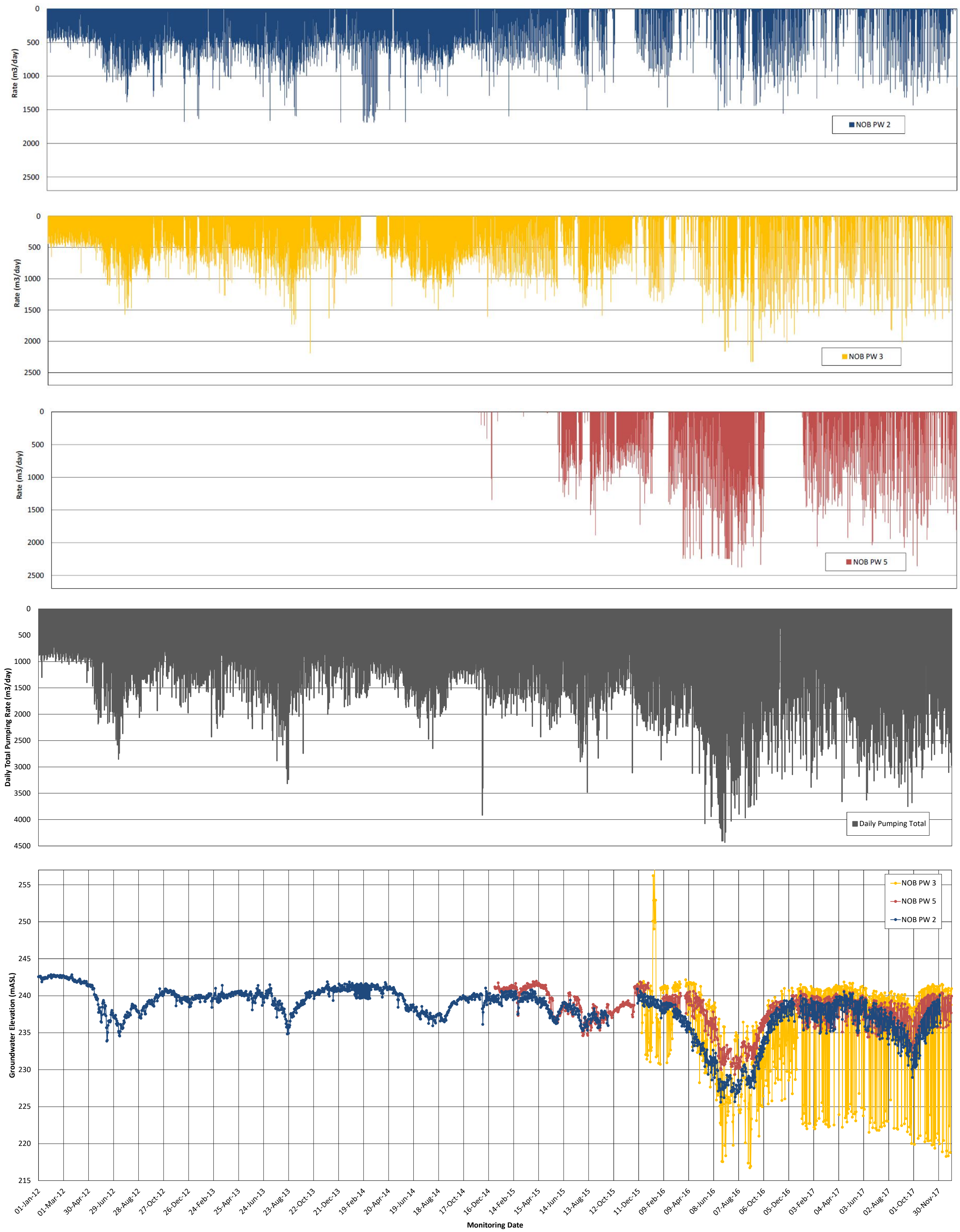
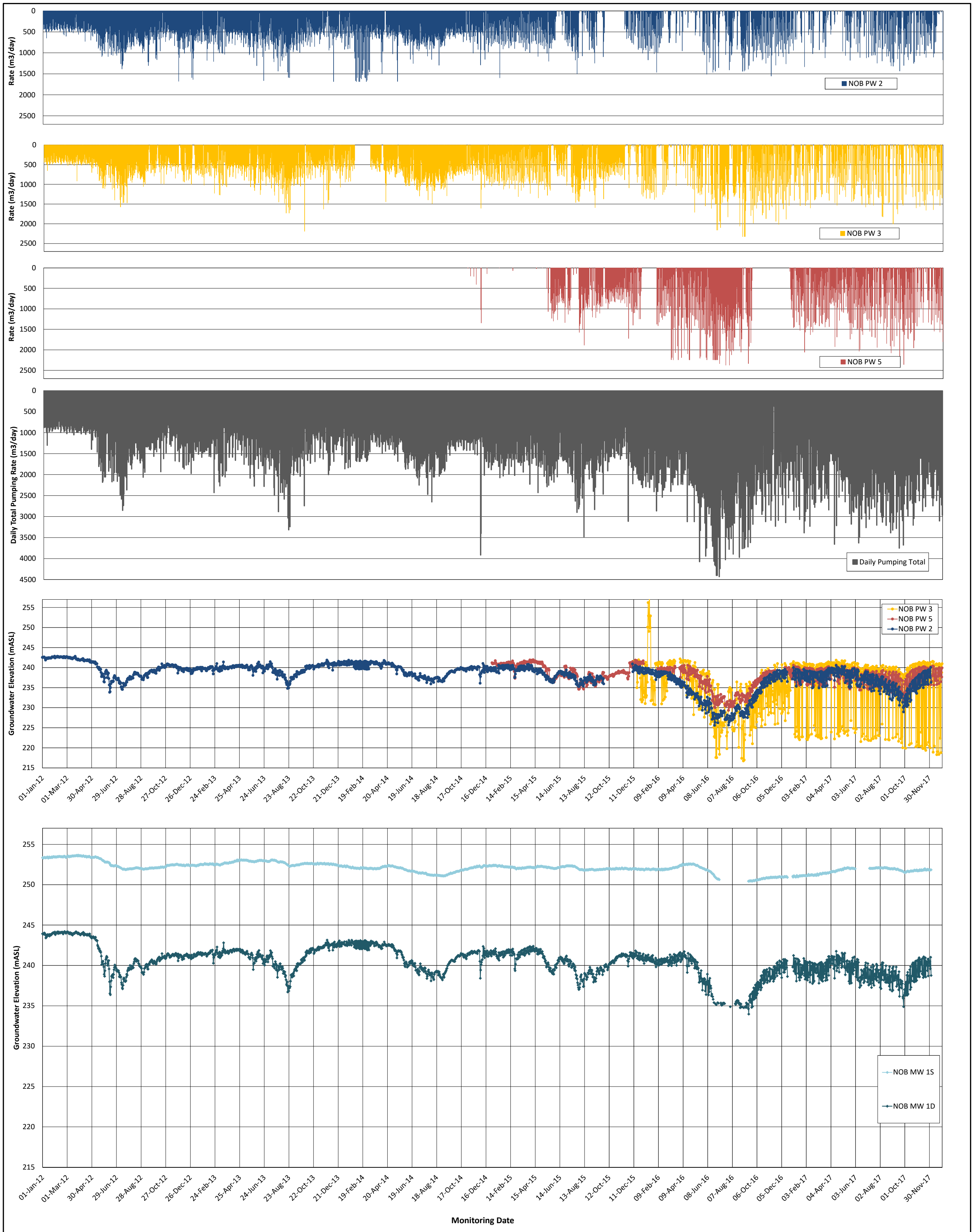


PALMER ENVIRONMENTAL CONSULTING GROUP INC.	Date: February 2018 Project: 17043	Drawn: MG Checked: JC	**Figure 13** **PW-2, PW-3 and PW-5 Gounrdwater Elevation**



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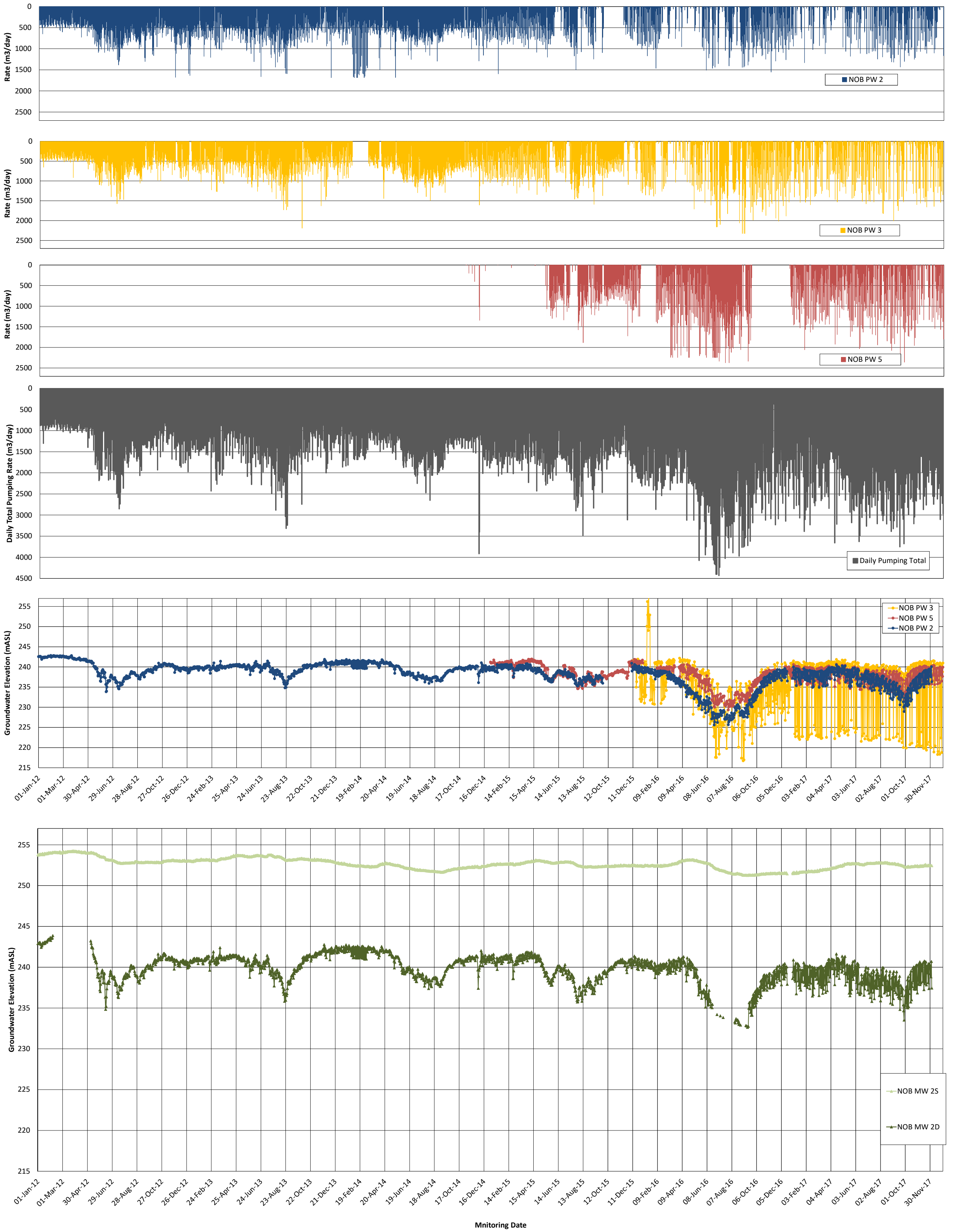
Date: February 2018 Drawn: MG

Project: 17043 Checked: JC

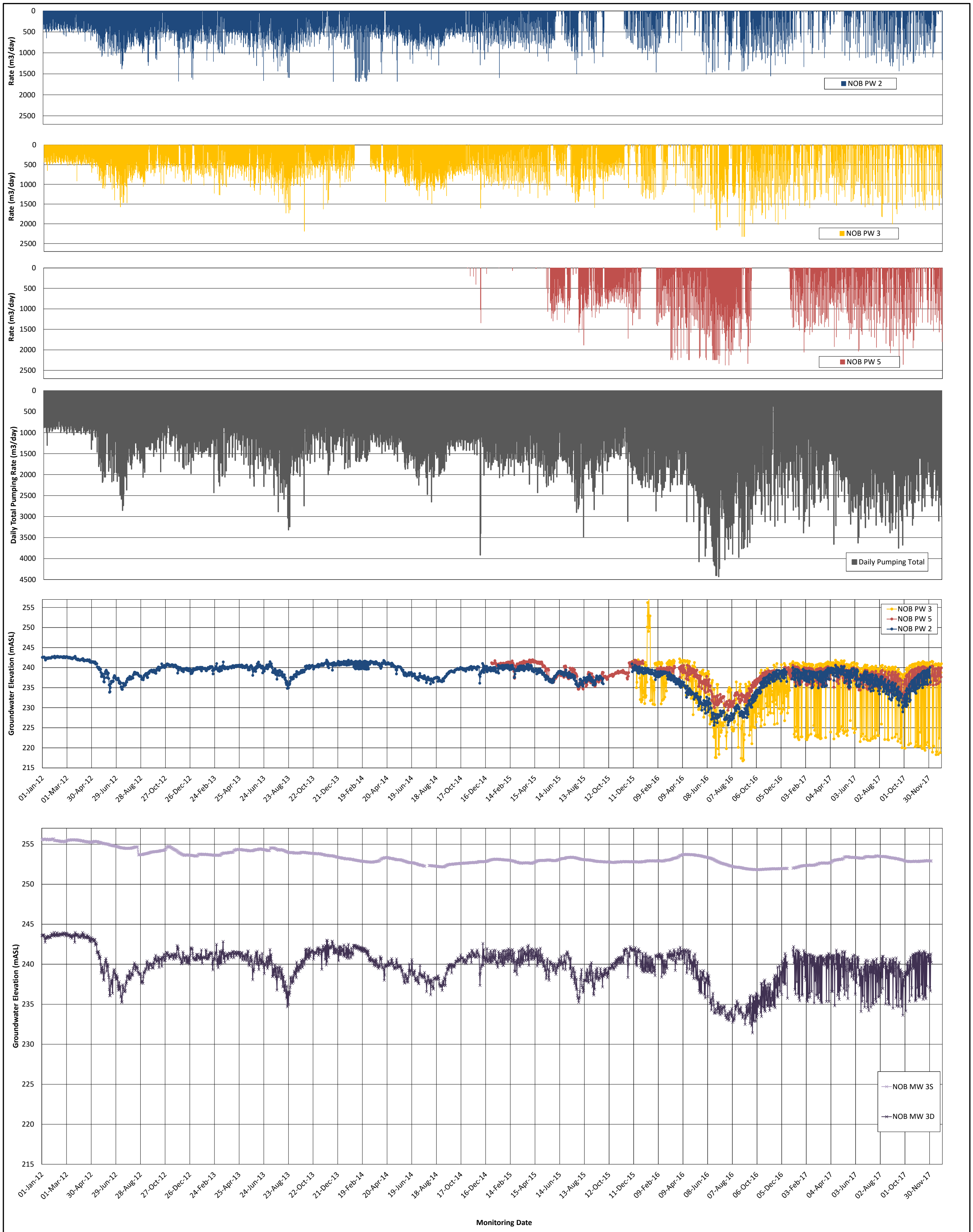
Figure 14

MW-1S and MW-1D Groundwater Elevation



PALMER ENVIRONMENTAL CONSULTING GROUP INC.

Date: February 2018	Drawn: MG	**Figure 15**
Project: 17043	Checked: JC	**MW-2S and MW-2D Groundwater Elevation**



PALMER ENVIRONMENTAL CONSULTING GROUP INC.

Date: February 2018

Drawn: MG

Project: 17043

Checked: JC

Figure 16

MW-3S and MW-3D Groundwater Elevation

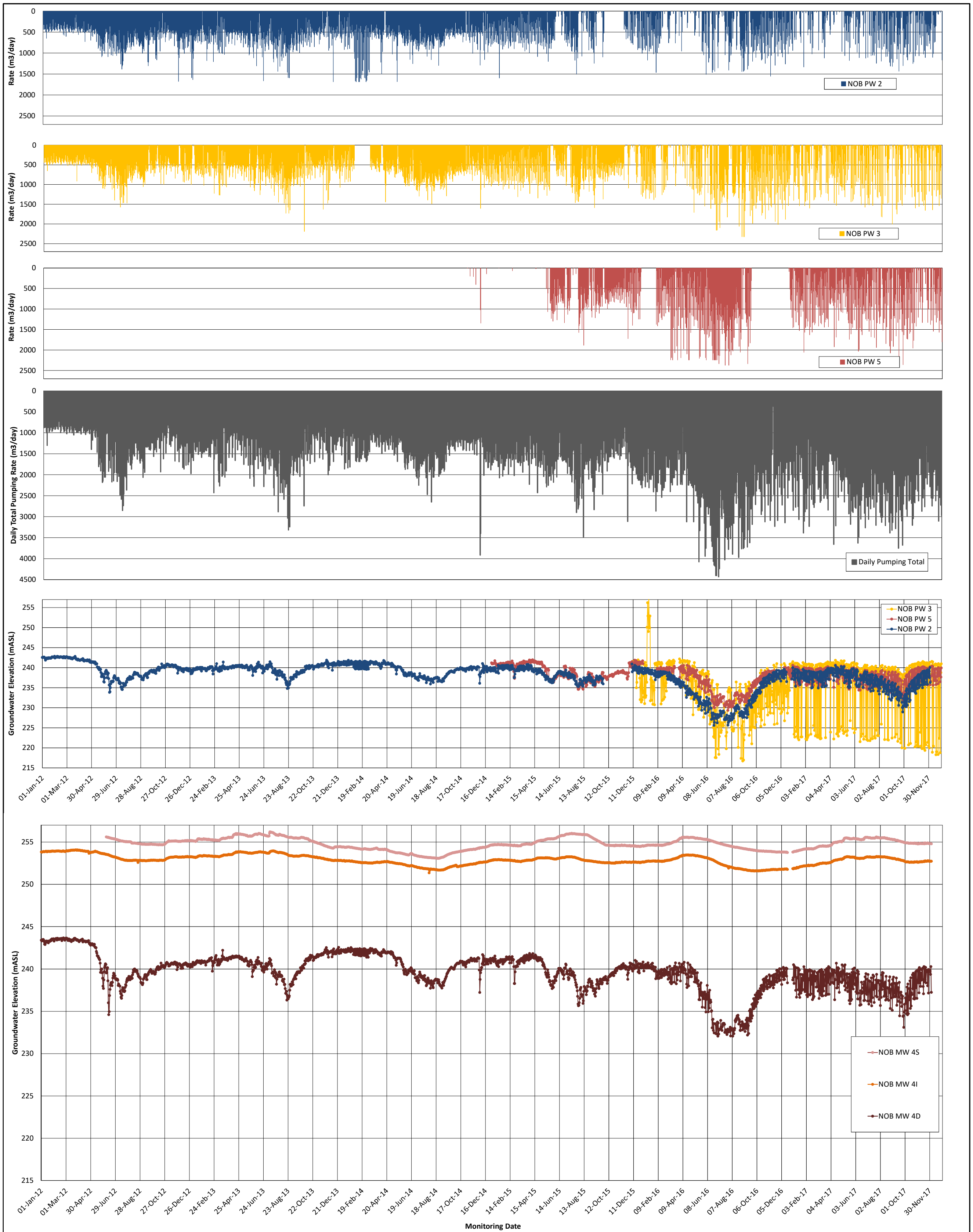


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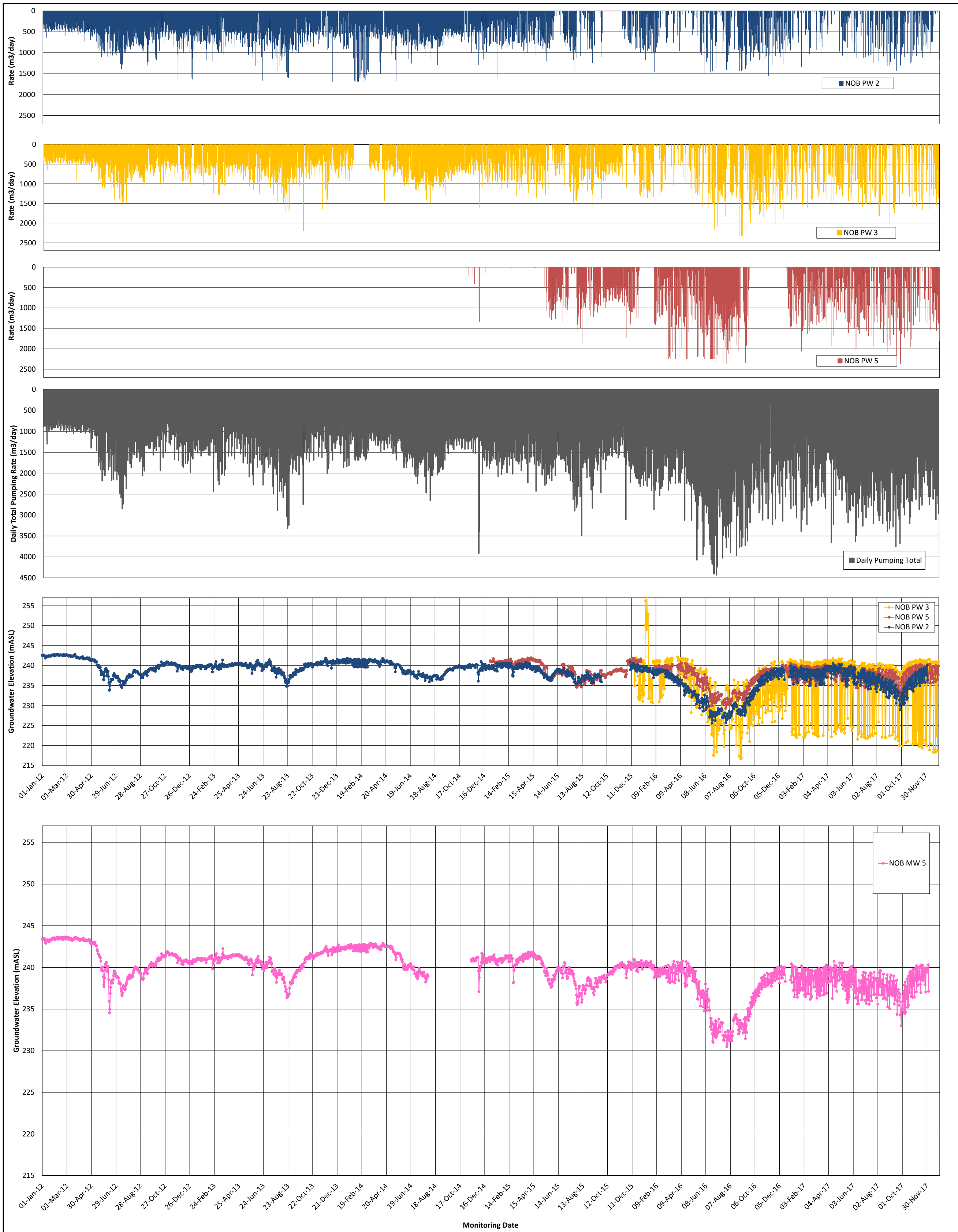
Figure 17

MW-4S, MW-4I, and MW-4D Groundwater Elevation



PALMER ENVIRONMENTAL CONSULTING GROUP INC.	Date: February 2018	Drawn: MG	**Figure 18**
	Project: 17043	Checked: JC	**MW-5 Groundwater Elevation**

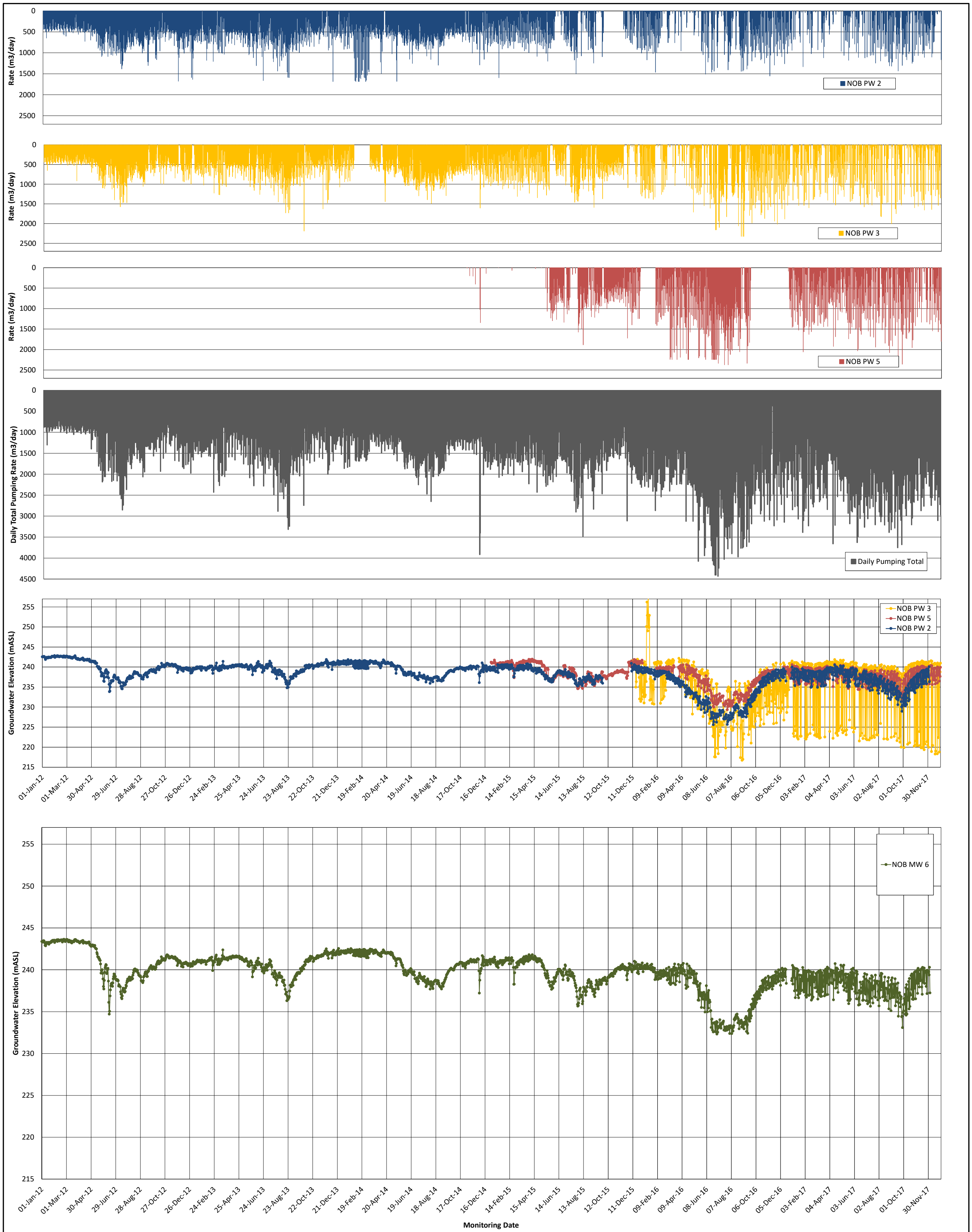


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Figure 19

MW-6 Groundwater Elevation

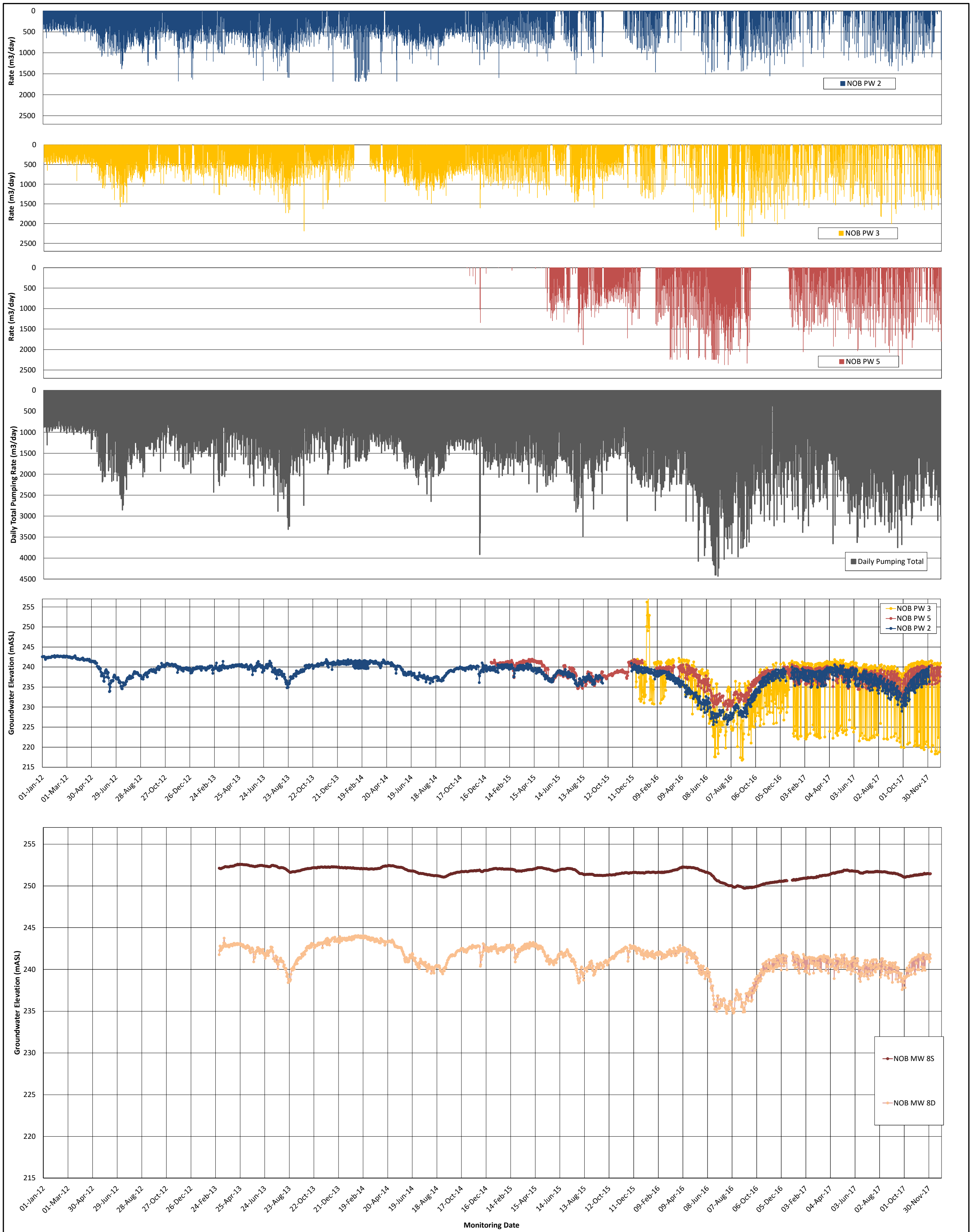

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Figure 20

MW-8S and MW-8D Groundwater Elevation

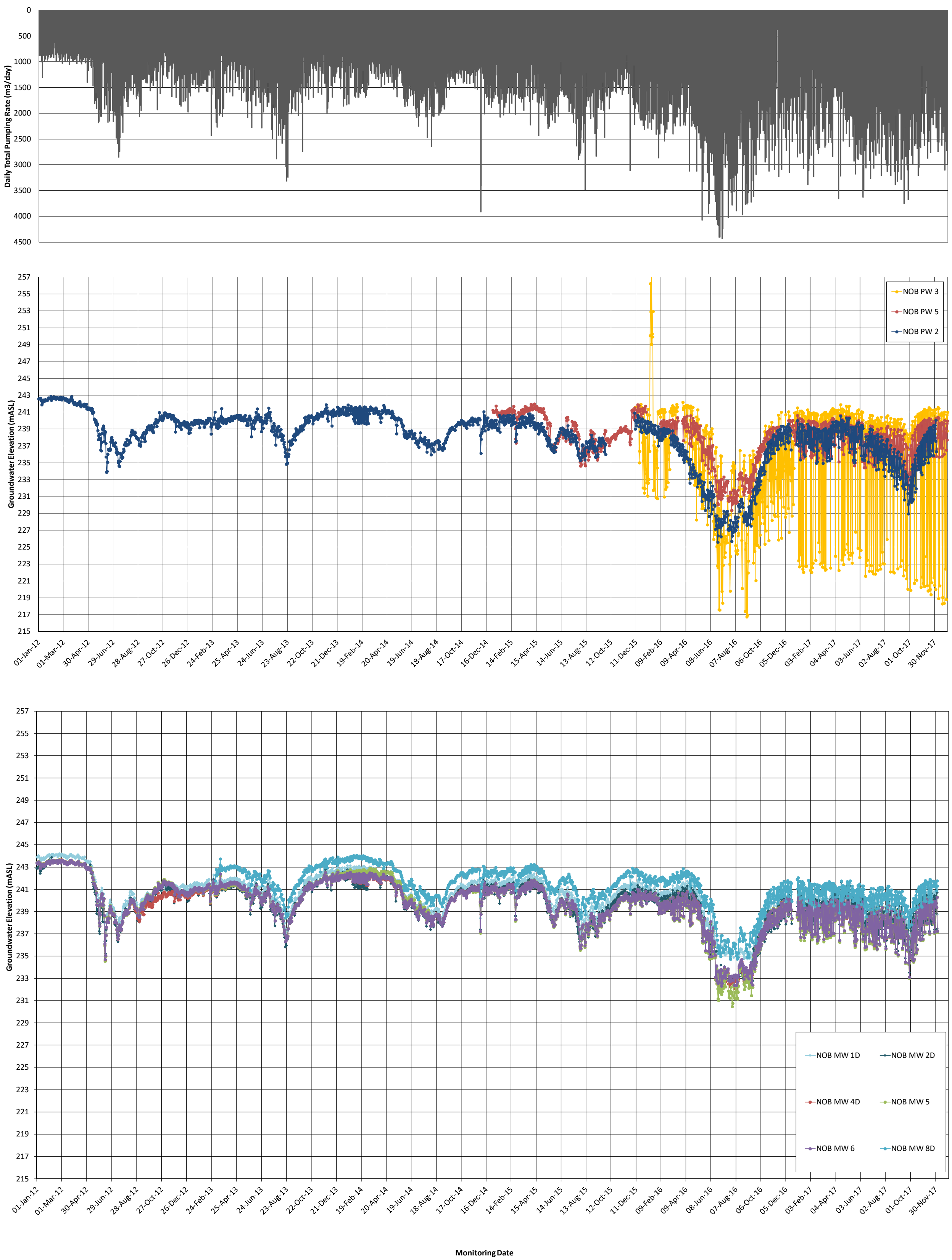

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Figure 21

Scarborough Formation Groundwater Elevations

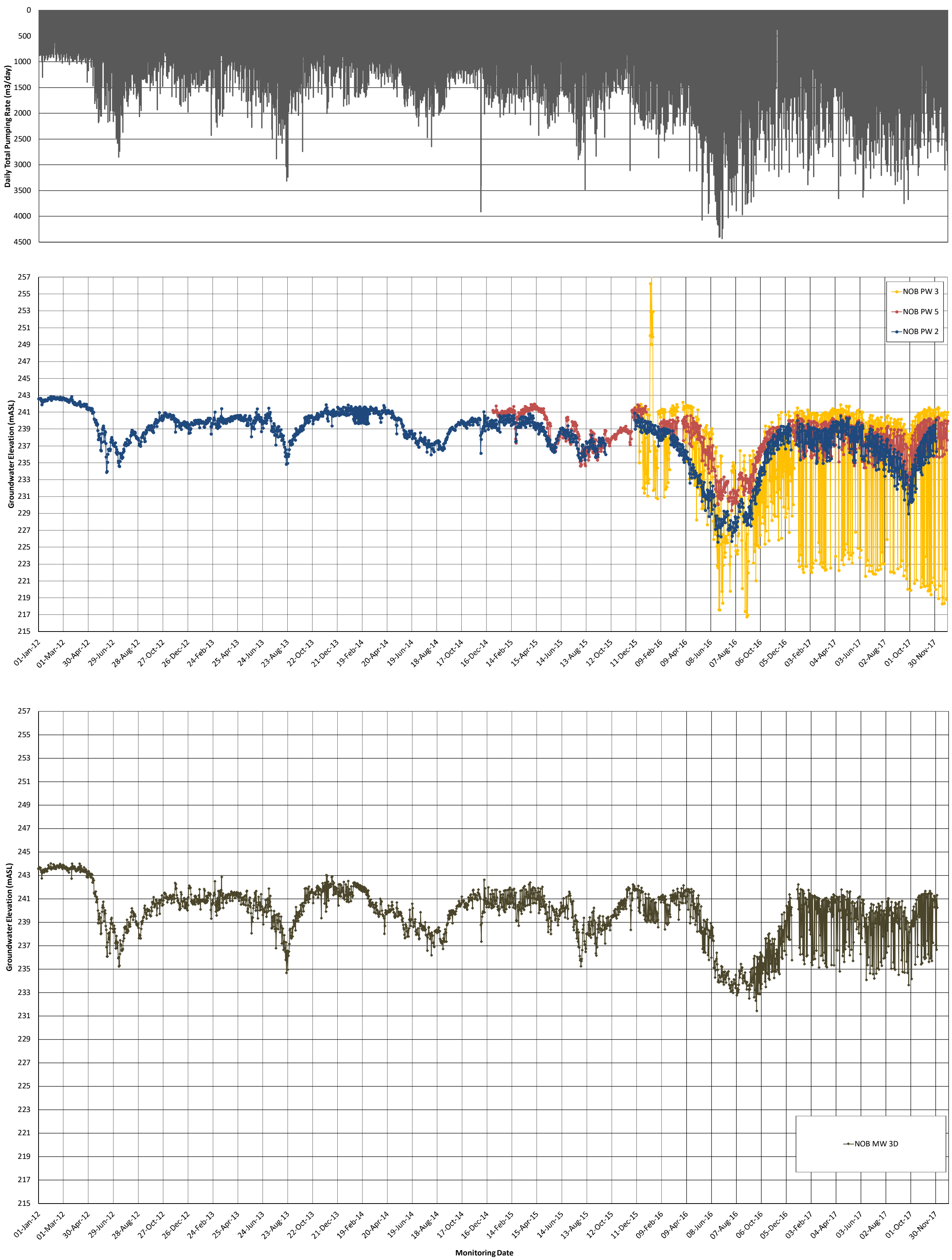

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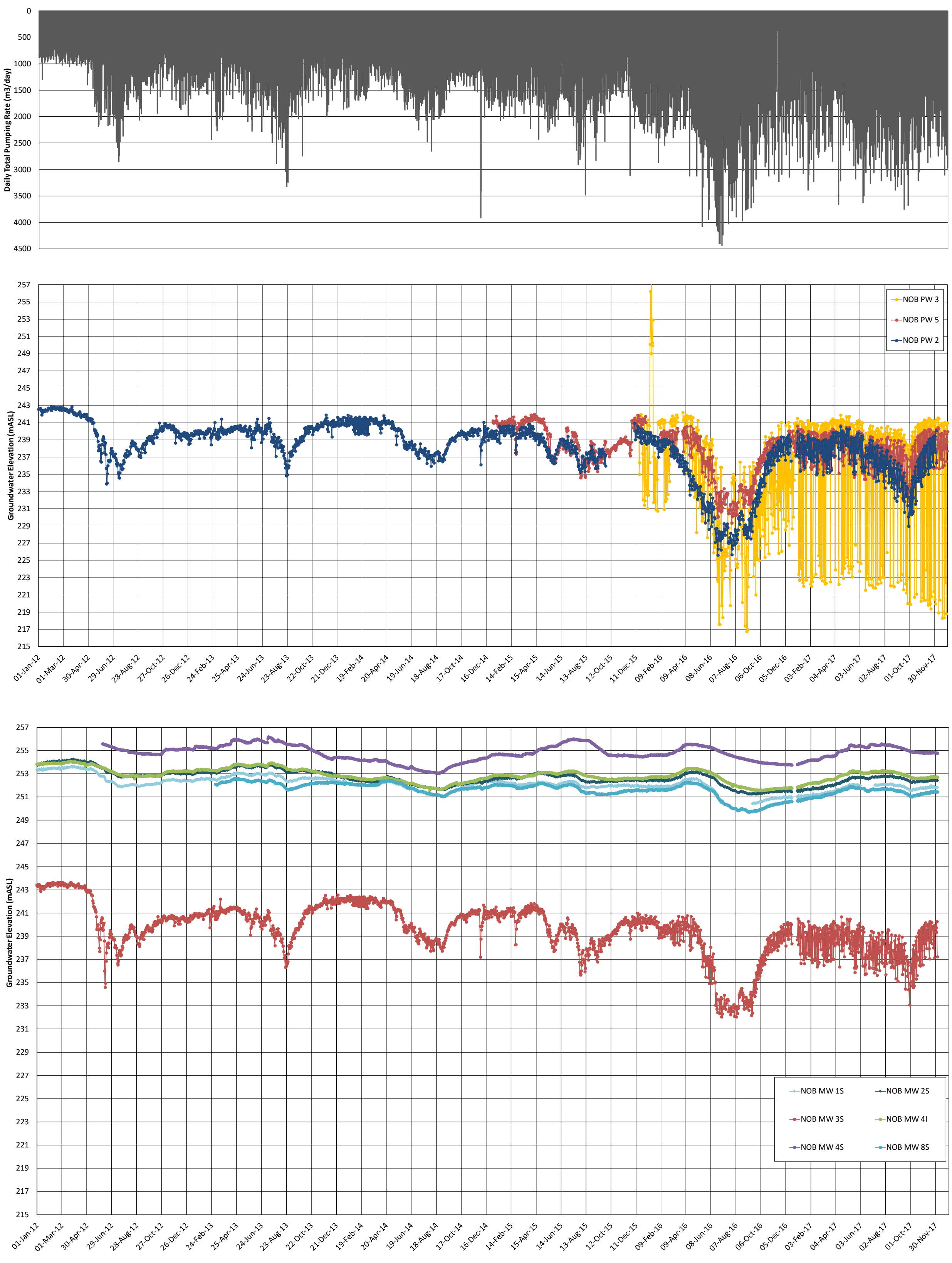
Figure 22

Thorncliffe Formation Groundwater Elevations



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Project: 17043

Checked: JC

Figure 23

ORAC Groundwater Elevations

of the discontinuous nature of the Sunnybrook Drift Aquitard in the Nobleton Area (**Appendix B**). In general, the monitoring wells screened in the upper and lower ORAC formations (MW-1S, 2S, 4I, 4S, 8S) did not respond to production well pumping, but rather to seasonal variations in precipitation and ET. However, as previously noted, an approximate 2 m water level decline has been observed since 2012 in the ORAC aquifer (Figure 23) and a strong hydraulic response was observed in MW-3S, which is screened in the Lower ORAC (**Figure 16**). The absence of the Newmarket Till Aquitard and the presence of tunnel channel deposits may have lead to this hydraulic connection between shallow and deep aquifer units at this location.

Between January 2012 and May 2015, groundwater level response in the monitoring wells and the production wells were relatively consistent, with drawdown occurring during periods of higher demand (late summer) and lower precipitation. Within the Scarborough Formation, the pumping related drawdown between 2012 and 2015 ranged between approximately 4 and 6 m (**Figure 21**). However, starting in June 2016, significant additional drawdown was observed. This drawdown coincided with significantly below average precipitation, PW-5 running a full capacity and new homes being connected to the town's water supply system. The magnitude of this additional drawdown is summarized in **Table 7** for each monitoring well and production well, and generally ranged from approximately 7 to 10 m or 3 – 4 m greater than the 2012 to 2015 range.

Table 7. 2016 Water Level Drawdown Summary

Well	Aquifer	Water Level Elevation (masl)		Sept 15, 2016 Drawdown (m)	Minimum 2016 Groundwater Elevation (masl)	Maximum 2016 Drawdown (m)
		15-Apr-16	15-Sep-16			
NOB MW 1D	Scarborough	241.19	234.63	6.56	233.97	7.22
NOB MW 1S	Lower ORAC	252.52	250.44	2.08	250.44	2.08
NOB MW 2D	Scarborough	240.57	232.76	7.81	232.63	7.94
NOB MW 2S	Lower ORAC	253.09	251.25	1.84	251.24	1.85
NOB MW 3D	Thorncliffe	241.75	235.06	6.68	231.42	10.32
NOB MW 3S	Lower ORAC	253.72	251.89	1.83	251.82	1.89
NOB MW 4D	Scarborough	239.80	233.29	6.51	232.05	7.75
NOB MW 4I	Lower ORAC	253.44	251.64	1.81	251.57	1.87
NOB MW 4S	Upper ORAC	255.55	254.12	1.43	254.01	1.54
NOB MW 5	Scarborough	239.71	233.02	6.69	230.47	9.25
NOB MW 6	Scarborough	239.78	233.42	6.36	232.32	7.46
NOB MW 8D	Scarborough	242.54	237.15	5.39	234.72	7.82
NOB MW 8S	Lower ORAC	252.24	249.75	2.48	249.71	2.53
NOB PW-2	Scarborough	235.36	229.00	6.37	225.68	9.69
NOB PW-3*	Scarborough	241.72	235.29	6.43	227.00	14.72

Well	Aquifer	Water Level Elevation (masl)		Sept 15, 2016 Drawdown (m)	Minimum 2016 Groundwater Elevation (masl)	Maximum 2016 Drawdown (m)
		15-Apr-16	15-Sep-16			
NOB PW-5	Scarborough	239.22	232.06	7.16	229.37	9.85

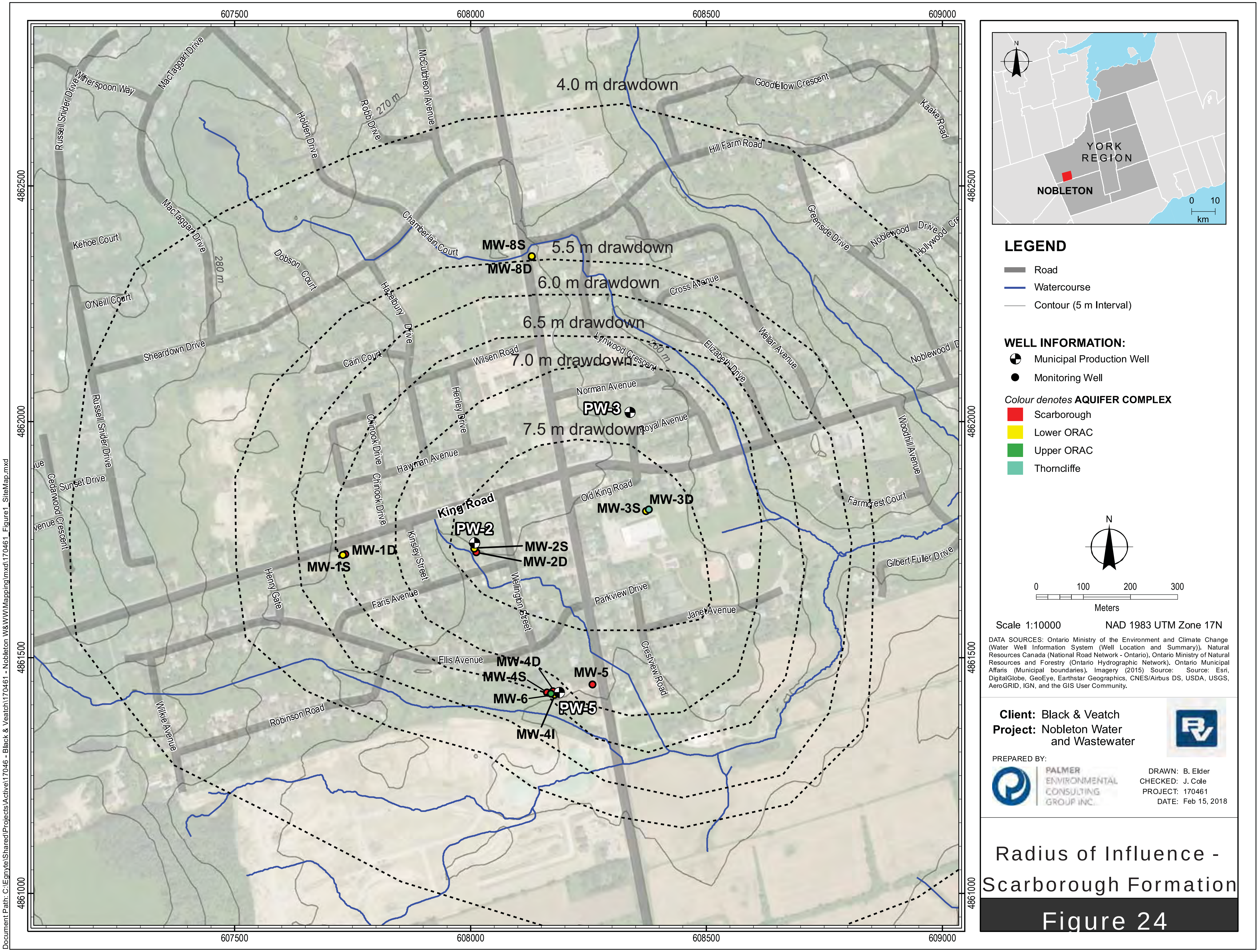
**interpreted to be at an elevation of approximately 227 masl*

4.2.4 Radius of Influence

An estimate of the radius of influence within the Scarborough Formation Aquifer from pumping under average conditions for PW-2, PW-3 and the now decommissioned PW-4 (located near the existing PW-5) was modeled by MMM as part of a groundwater resource exploration study (MMM, 2007). This model assumed that each well would pump at 663 m^3/day for a total pumping rate of 1,990 m^3/day. The resulting radius of influence to a drawdown of 0.3 m was determined to be 2,500 and 3,000 m, which generally corresponds to the Nobleton municipal boundary.

Using the measured drawdown data on September 15, 2016 (as presented in **Table 7**) when the combined pumping rate was 3,312 m^3/day, the estimated radius of influence in the Scarborough Formation was modeled in AQTESOLV using a forward analytical solution. The solution was fitted to the observed drawdown in MW-1D, 2D, 4D, 5, 6, and 8D and presented on **Figure 24**. The results of the model are presented on **Figure 25**. The radius of influence to 0.3 m drawdown is estimated to be 3,800 m. This additional drawdown brings the radius of influence outside of the Nobleton municipal boundary.

A drawdown simulation was not completed for the estimated 8,689 m^3/day of required groundwater production to meet peak 2031 population forecasted demand as it is not clear if the existing production wells can support this production rate. Additional hydraulic testing will be required to confirm.



*Contains public sector Information made available under The Regional Municipality of York's Open Data Licence and information licensed under the Open Government Licence - Ontario and Canada.

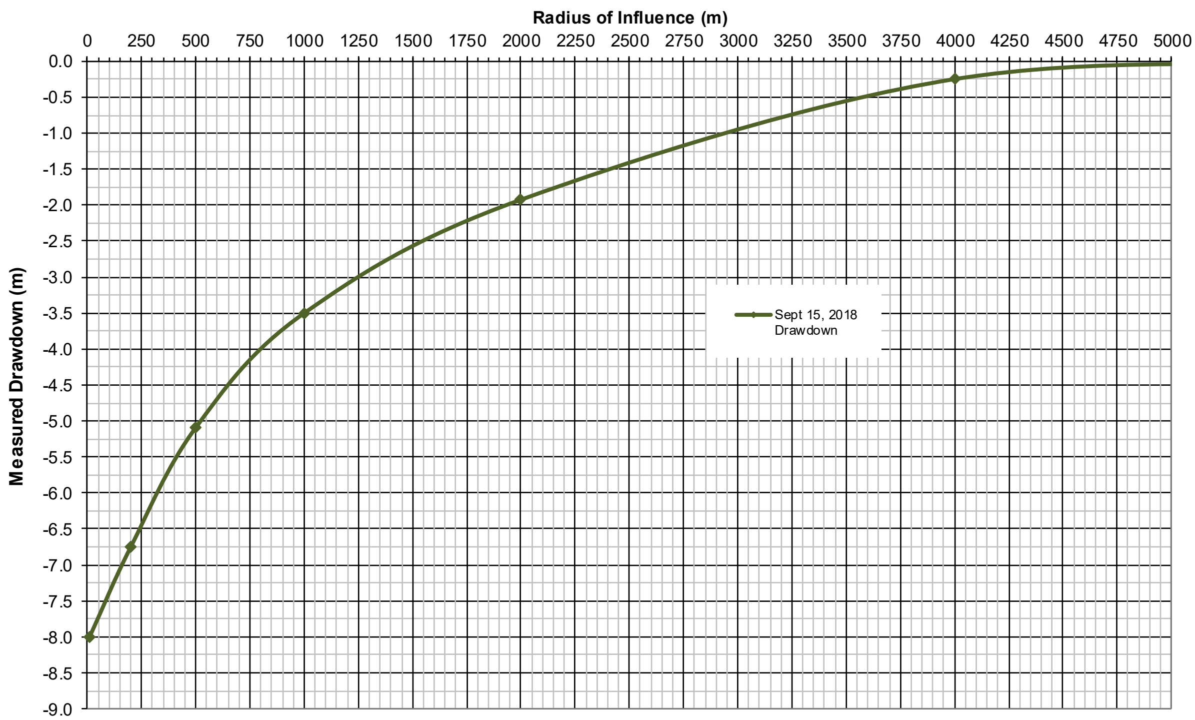


Figure 25. AQTESOLV Forward Solution – Estimated Radius of Influence

4.2.5 Available Drawdown

An assessment of available drawdown is presented in **Table 8**. Taking into consideration the top of the Scarborough Aquifer and the presence of downhole equipment within the wells, is estimated that PW-2, PW-3 and PW-5, have approximately 74.5, 56.7, and 72.2 m of available drawdown, respectively. While 2016 showed greater than average water level drawdown due to increased pumping, less than 26% of the available drawdown was utilized in each well.

Table 8. Estimated Available Drawdown

Well	Top of Screened Interval (masl)	Approx. Top of Scarborough Aquifer (masl)	Estimated Static Water Level Elevation (masl)	Estimated Length of Downhole Equipment (pump, packer, lead pipe, etc.) (m)	Estimated Available Drawdown from Static (m)	Approximate Summer 2016 Maximum Drawdown (m)	% Available Drawdown used in 2016
PW-2	161.46	162.1	241	5	74.5	9.69	13%
PW-3	179.29	179.9	241	5	56.7	14.72	26%
PW-5	163.83	166.6	241	5	72.2	9.85	14%

It is recognized that the specific capacity will likely decrease, and well interference and well losses will likely increase as the pumping rate increases, but these results support that sufficient available drawdown available to increase the yield from each well. PW-2 and PW-5 have the highest Transmissivity, Specific Yield, and available drawdown, and it is recommended that additional well testing focus on these two wells.

The observed hydraulic connection between the Thorncliffe and Scarborough Aquifer formations at MW-3D should be considered when assessing the available drawdown (**Figure 22**). The top of the Thorncliffe Aquifer is located at approximately 200 masl, and as there is a hydraulic connection, it may not be desirable to draw the water level down in the production wells to below the Thorncliffe Formation. This would reduce the available drawdown by approximately 30 m for each production well.

There is also a hydraulic connection to the Lower ORAC at MW-3S (**Figure 23**), and the potential effects of increased drawdown in the shallow aquifer would need to be considered under any increased pumping scenario. No other monitoring well screened in the shallow aquifer respond to pumping at PW-2,3 or 5, although a general, long-term water level decline has been observed.

5. Summary and Recommendations for Additional Water Supply Capacity Assessments

Based on the results of the hydrogeological assessment, the community of Nobleton will require additional permitted water supply capacity in the short-term and to meet the 2031 population forecast of 10,800 persons. Fortunately, the Nobleton area has an extensive confined aquifer (Scarborough Formation Aquifer) that can provide additional water supply capacity through either increased pumping of the existing water supply wells (PW-2, PW-3 and PW-5) and/ or through the identification and installation of a new municipal supply well.

An analysis of *average demand* indicates that the existing municipal production wells can meet the average 2031 demand under the existing PTTW. However, the peak 2016 demand with a population of 5,500 was 4,433 m^3/day, which is 99% of the current PTTW water taking rate. By 2031, the population will increase by 96% to 10,800, and without considering conservation efforts, the peak demand is expected to be approximately 8,689 m^3/day or 96% more than present demand. In addition, a redundancy in water supply capacity in the range of 2,500 to 4,000 m^3/day is required to secure a firm capacity for Nobleton.

The following provides a discussion of three hydrogeological options to increase the water supply capacity to meet 2031 demand.

5.1 Simultaneous Pumping of all Existing Wells

The existing Nobleton production wells (particularly PW-2 and PW-5) have substantial additional drawdown and supply capacity that can likely provide additional water supply capacity. However, the existing PTTW only allows for pumping of two of the three production wells simultaneously. Interference effects between the wells have not previously been directly studied to support simultaneous pumping of all three wells. Without taking into consideration interference effects, the potential combined water taking rate from the three existing production wells is 6,956 m^3/day, which is sufficient to meet average and peak demand in the short-term but provides no redundancy and does not increase the firm capacity of the Nobleton water supply system. A change to the existing Category 3 PTTW with the MOECC would be required to support this additional water taking.

To assess the interference effects, PECG recommends that a Category 2 PTTW is obtained to allow for a combined pumping test of PW-2, PW-3 and PW-5 for a period of 72-hours. If feasible, all wells should be shut-down for approximately 24-hour and water levels recovered to static prior to starting the test. It is expected that the effects will be similar to that measured during the period between April and September 2016. Completing this test during the spring when water demand is low and groundwater levels are high would be most practical.

5.2 Increase Permitted Capacity of Existing Well(s)

A series of step drawdown pumping tests could be completed at each of the three existing production wells in accordance with Section 14B.6.2.3 of Groundwater Development and Wellhouse Design Manual to confirm an increased sustainable yield and to determine if additional water supply capacity is available. This assessment would consider understanding the potential impacts to the local aquifer as a result of any additional water taking increases. There still remains a potential for significant interference effects between the production wells and increased hydraulic connections to the Thorncliffe and ORAC aquifers that may limit the ability to permit these wells at higher rates.

Hydraulic testing at PW-5 indicates a specific capacity of approximately 930 m^3/day/m (10.8 L/sec/m). With an available drawdown estimated to be approximately 72.2 m, significant additional water supply capacity could be obtained from this well. It is recognized that well efficiency and specific capacity will decrease with increased pumping rates, however an additional 3 m of drawdown could add 2,790 m^3/day to the existing production capacity of 2,496 m^3/day. This would more than double the production rate to 5,286 m^3/day.

PW-3 has a specific capacity of 203 m^3/day/m and an estimated available drawdown of approximately 56.7 m. An additional 5 m of drawdown could add 1,1015 m^3/day to the existing rate of 2,496 m^3/day for a total water taking rate of 3,511 m^3/day.

PW-2 has a specific capacity of 267 m^3/day/m and an estimated available drawdown of 74.5 m. An additional 5 m of drawdown could add 1,335 m^3/day to the existing rate of 1,964 m^3/day for a total water taking rate of 3,299 m^3/day.

As previously discussed, the specific capacity will likely decrease, and well interference and well losses will likely increase as the pumping rate increases. These effects don’t preclude that additional water supply capacity could be gained from each well, however it would need to be demonstrated that the increased production rates are sustainable.

5.3 New Groundwater Supply Well

While it is likely that additional water supply capacity can be achieved through simultaneous pumping of PW-2, PW-3 and PW-5, and through increasing the permitted capacity of the wells, the firm capacity requirements to meet the 2031 demand may necessitate the installation of a new municipal supply well.

A fourth municipal production well would also target the Scarborough Aquifer, which is expected to be of sufficient extent and have sufficient capacity to host an additional supply well without mining the aquifer. Assuming the additional production well has a yield similar to existing production PW-5, and that the production of the new well will not interfere with the existing yield from the existing wells, the total water supply capacity could potentially be increased by approximately 2,500 to 5,000 m^3/day. A detailed Hydrogeological Resource Investigation will be needed to evaluate the possibility of locating, testing and installing a new supply well.

6. Closure

Thank you for the opportunity to be part of your team on this project. Should you have any questions or comments about the report, please don't hesitate to contact the undersigned.

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Senior Hydrogeologist

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Principal, Senior Hydrogeologist

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