Hanlon Creek Business Park
2014 Consolidated Monitoring Report

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Natural Resource Solutions Inc.
Aquatic, Terrestrial and Wetland Biologists

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Introduction

A consolidation of the monitoring on the Hanlon Creek Business Park (HCBP) Lands is required as a condition of approval of the *HCBP Environmental Implementation Report 2009* (EIR) prepared by Natural Resource Solutions Inc. Standard Operating Procedures for this monitoring can be found in a report titled *Hanlon Creek Business Park Consolidated Monitoring Program*, prepared by NRSI in 2010.

Pre-construction monitoring began in 2006 and continued for 4 years. Construction-phase monitoring began in 2010. Monitoring occurs either at specific times of the year, and certain components of groundwater and surface water occur year round. Annual reporting occurs according to the calendar year. A Rapid Assessment and Action Protocol (RAAP) is in place to address immediate monitoring concerns, with a focus on surface water temperature and turbidity.

Construction commenced in late 2009 and has continued each year and through 2014. Construction activity in Phase 1, Stage 3 lands in 2014 included the operation of one commercial building and two industrial buildings previously constructed, and the construction of one building on part of Block 14 at 230 Hanlon Creek Boulevard. Construction in Phase 2 lands in 2014 included the preliminary grading of Blocks 8, 9 and 26, and the use of the Laird Road overpass. Construction inspection in 2014 was conducted by Natural Resource Solutions Inc. (NRSI).

Performance monitoring in 2014 was conducted by Banks Groundwater Engineering Limited, AECOM and NRSI. Monitoring components included groundwater levels, temperature and water quality at 37 monitoring wells and 19 mini-piezometers; stream flow, temperature and water quality at 11 stream stations and within 3 stormwater management ponds; fish and benthic invertebrates at 5 stream stations; and vegetation, breeding birds and amphibians at 11 vegetation plots plus additional bird and amphibian stations.

Results

In 2014, groundwater levels are easily explained by the weather including the patterns of precipitation throughout the year. The highest groundwater levels observed in monitors equipped with data loggers occurred during the months of January, April, September, and November. These high levels correspond to thaw events in the winter and precipitation patterns the rest of the year. The lowest groundwater levels occurred in early March, early September and early November. These periods of low levels were considered normal, as groundwater elevations at all monitoring stations remained within the normal range throughout 2014.

During the months of January, February and March, groundwater levels at Core PSW and Downey Road PSW monitoring stations were within the typical range for this time of year, fluctuating in direct response to maximum daily temperatures above 0°C and corresponding periods of infiltrating precipitation. Groundwater levels began a gradual decline in mid-May, with occasional short-duration increases in response to precipitation events measuring more than 15 mm in a 24-hour period. Most of the lowest levels observed in each monitoring well in 2014 occurred during late-August and early-September. The 2014 summer levels were generally comparable to 2013 summer levels, which were above the low levels observed during the drought in the summer of 2012. At many Core PSW monitoring stations, groundwater levels rose in response to precipitation in early-September and again in October.

Regarding site-wide patterns in groundwater elevations, the smallest fluctuations occurred in and adjacent to the core wetland and Hanlon Creek Tributary ‘A’. Shallow depths to groundwater and the occurrence of groundwater discharge to these surface water features naturally limit the range of groundwater elevations in these areas. Groundwater elevations varied more widely over the year at perimeter locations where groundwater recharge to the medium- to coarse-grained deposits is most significant.

Altogether, climate had the greatest, if not only, influence on groundwater levels across the HCBP in 2014. There were no apparent changes in groundwater levels that could be attributed to construction activities during 2014 within the HCBP.

Surface water baseflows in Tributary A in 2014 were greater than those in 2013 at seven of 10 stations. Only station HC-A(03), the farthest upstream in Tributary A, experienced lower baseflows in 2014 compared to 2013. The generally greater baseflows occurred in spite of total precipitation in 2014 that was lower than in 2013.

The discharge from Pond 4 was observed to be near continuous again in 2014 causing elevated baseflow levels at HC-A(04), which is located a short distance downstream of Pond 4. The pond interacts with groundwater flowing in a northwesterly direction, and provides a more direct pathway for discharge to Tributary A. The continuous discharge has resulted in the observed elevated baseflows in Tributary A, and has also affected summer water temperatures in Tributary A. The bottom draw outlet ensures that the coolest water in the pond is being discharged, and the cooling trench also receives groundwater directly, further reducing discharge temperatures. Nevertheless, the resulting discharge temperature is greater than the stream temperatures in Tributary A in the summer.

During summer months of 2014, Tributary A stations HC-A(04) and HC-A(06), located downstream of the Pond 4 outlet, recorded high average temperatures and little daily fluctuation due to the influence of Pond 4's continuous discharge, as compared to HC-A(03) which is not impacted by pond discharge. Downstream stations on Tributary A which are more exposed such as HC-A(10), HC-A(12), HC-A(13) and HC-A(14), and those with a wider flow channel and shallower depths (HC-A(09)), show the highest daily variation in temperature as there is greater opportunity for solar radiation impact. Station HC-A(08) shows the lowest temperatures and daily temperature variation during the summer, indicating the presence of groundwater inputs in Tributary A1 where this station is located. The resulting temperatures in the summer of 2014 were determined to be above the preferred temperatures for Brook Trout.

Groundwater quality in 2014 was generally within the applicable Ontario Drinking Water Quality Standards (ODWQS) criteria for concentrations of the parameters analyzed, with some exceptions for nitrate, metals, sodium and hardness. Colour, turbidity, total dissolved solids and dissolved organic carbon (DOC) generally exceeded the respective ODWQS concentrations, and this is typical for these parameters in monitoring wells.

For surface water quality in 2014, the majority of the stream sites were within the ranges of the Provincial Water Quality Objectives (PWQO). During the stream baseflow monitoring event on October 9, the dissolved oxygen (DO) was below PWQO minimum level at station HC-A(12), which may be attributable to a below-average flow rate due to high temperatures and an extended period of no precipitation. The pH levels were more acidic than the PWQO guideline range at two of the stations, each on a different sampling date. Monitoring of turbidity at three stations occurred in 2014, although sediment accumulation and biofouling resulted in inaccurate readings for extended periods at each location.

Benthic invertebrate monitoring in 2014 showed a trend of decreasing Ephemeroptera, Plecoptera and Trichoptera (EPT) richness at three stations (BTH-001, BTH-003, and BTH-005), and at this point the cause is not clear. The continuous discharge from SWM Pond 4 is a potential cause, but the results by station do not make a clear or consistent connection. In addition, two stations (BTH-002 and BTH-004) resulted in sequential "Impact" determinations from the PMA-Analysis. The occurrence of 'impact' determinations at both of these stations suggests a change in the quality of the benthic community at these stations. These stations are in sequence downstream of the confluence of Tributary A and Tributary A1. The cause of these determinations is not clear at this point in time. Monitoring using the PMA analysis should continue with the intention of determining whether or not a 'no impact' determination is observed again at these stations. Both the decrease in EPT richness and the sequencial PMA impact determinations represent threshold exceedances.

Fish monitoring in 2014 resulted in the capture of a total of 454 individual fish representing six different species. The total catch in 2014 represents a decrease compared to 2013 when an unusually high number of fish were captured. Five of the six fish species captured in 2014 are known previously from the monitoring program, with the exception of pumpkinseed, which was captured for the first time. All but one exhibit a cool-water thermal regime, with the exception being pumpkinseed, which prefers warmer waters (Eakins 2014). There was a reduction in the number of fish captured by 50% at two stations in 2014, which represents a threshold exceedance.

Vegetation monitoring in 2014 showed largely stable vegetation conditions with only a few exceptions. A total of 136 vascular flora species were recorded in 2014. Three species were recorded for the first time in 2014: Wool-grass (*Scirpus cyperinus var. cyperinus*) and Redtop (*Agrostis stolonifera*) in Plot 6, and a Bur Oak (*Quercus macrocarpa*) sapling in Plot 7. A total of 12 regionally significant species have been observed in the plots between 2006 and 2014. In 2014, Meadow Horsetail (*Equisetum pratense*) and Rough-leaved Goldenrod (*Solidago patula*) were observed and are considered rare within Wellington County. None of the species observed are federally or provincially significant.

The coefficient of wetness continued to show that two plots (Plots 3 and 5) are upland sites while the remaining nine plots are in wetlands. Plot 1 continued to be the wettest plot, and Plot 3 continued to be the driest. Plot 7, located within a White Cedar-Hardwood mixed swamp, had a positive CW value for the first time, compared to its typical range between 0 and -1. The change is small and may be a result of sampling slightly different locations in the hummocky terrain. Plots 16 and 18 demonstrated the continuation of a drying trend that is not explained by groundwater levels but may be a result of changes to surface hydrology.

The coefficient of conservatism (CC) values at five of the plots had average results between 4 and 5, which are consistently the highest values from year to year and can be interpreted as having plant species that are associated with a specific plant community but can tolerate moderate disturbance. Two of the plots (Plots 6 and 9) had values between 2 and 3 indicating the presence of plant species that are more tolerant of disturbance.

The Natural Area Index (NAI) combines the CC with native species to provide a more stable assessment of the vegetation. NAI values were generally stable compared to recent years, increasing at some stations and decreasing at others. However, the values at many of the stations are low relative to the overall monitoring period. There are a variety of explanations, including the potential for the addition or subtraction of one species to have a substantial effect on the NAI value at a station with low diversity. It is also believed that the drought conditions in 2012 are likely to have a lingering effect on the NAI values for most of the stations.

The numbers of non-native species have remained stable throughout monitoring from 2006 to 2014, with 16 recorded within vegetation pots in 2014. By category of plants, observations were made of 103 herbaceous plant species and 22 shrub species. The number and composition of trees was unchanged.

A total of 51 bird species were observed during breeding bird monitoring in 2014, with 42 species documented during the formal point counts. Of the 42 species, 15 exhibited possible breeding evidence, 23 exhibited probable, two were confirmed, and two did not show breeding evidence. The most abundant species observed during 2014 surveys were Red-Winged Blackbird (*Agelaius phoeniceus*), and American Robin (*Turdus migratorius*), both with 11% of the observations during breeding bird point counts. These were followed by Song Sparrow (*Melospiza melodia*) at 9%, and five other species with proportions of 4% to 6%.

In general, the diversity of bird species at each plot in 2014 was similar to those numbers documented between 2006 and 2011, with 2012 and 2013 appearing as exceptional years of high diversity across the study area. The 2014 abundance reflects the overall average since monitoring began in 2006. Similar to species diversity, breeding bird abundance showed a notable spike during the 2012 and 2013 monitoring years and 2014 data reflects abundance data observed between 2006 and 2011.

NRSI observed three species that are considered Threatened federally and provincially: Barn Swallow, Bobolink, and Eastern Meadowlark. Bobolink has been observed each monitoring year with probable breeding evidence documented in 2010 and 2012 through 2014. In 2014, Bobolink was observed only within Plot 20, located in the Phase 3 lands. Barnswallow was recorded as a fly-over for Plots 9, 19 and 20, all located in Phase 3 lands. The Crawley farmhouse which exists near Plot 20 may provide suitable nesting habitat for Barn Swallow; however, no breeding evidence was observed at Plot 20 or within the subject property in 2014. Barn Swallow may also be nesting outside of the subject property in barns along Forestell Road or Downey Road and utilizing the subject property for foraging habitat. Eastern Meadowlark was recorded in Plot 19 (Phase 3) as showing possible breeding evidence in 2014 and has been recorded showing possible or probable breeding evidence on site every year since 2007. As noted in previous monitoring reports, the establishment of old field meadow throughout Phase 3 is providing suitable breeding habitat for open country breeding bird species.

Eastern Wood-Pewee (*Contopus virens*) is listed as Special Concern federally and provincially. A single singing male was observed at Plots 2, 11 and 19 during the June 7, 2014 survey with a single singing male at Plots 2 and 19 during the second visit denoting probable breeding evidence.

Five amphibian species were recorded during evening call count surveys in 2014; Spring Peeper (*Pseudacris crucifer crucifer*), Wood Frog (*Lithobates sylvatica*), Northern Leopard Frog (*Rana pipiens*), Green Frog (*Rana clamitans melanota*) and Gray Treefrog (*Hyla versicolor*). Since 2006, the number of species recorded during the calling anuran surveys has fluctuated. The five amphibian species recorded calling in 2014 is above the annual average of 3.6 species recorded in previous years. Species recorded during surveys have fluctuated over the eight-year monitoring period, with as many as six species recorded during 2009 surveys and none recorded during the first preconstruction monitoring year (2006).

<u>Issues</u>

Water temperatures during summer months of 2014 continued to be elevated as a result of the effects of SWM Pond 4. While surface water temperatures were somewhat lower in 2014 compared to 2012 and 2013, with the weather being normal to somewhat cool compared to other previous years, the influence of SWM Pond 4 continued to be evident in 2014. The evidence is focused on the stations on Tributary A that are the nearest to the SWM Pond 4 outlet. Temperatures did not exceed 22°C or 24°C at those stations, but the thermal effects are evident in the proportion of the summer that the temperature was above 19°C, and by the thermal regime classification in 2014 compared to pre-construction data. These elevated water temperatures are of concern based on the goal of maintaining a suitable thermal regime for Brook Trout, a cold water fish species that inhabit the Hanlon Creek system.

Two potential modes of impact by SWM Pond 4 were previously discussed the 2012 and 2013 consolidated monitoring reports. The first mode is the water that is discharging to

Tributary A through the SWM Pond 4 outlet; the second is the pond's effects on adjacent groundwater that may eventually discharge to Tributary A as groundwater.

All five benthic monitoring stations experience threshold exceedances in 2014. Two stations, BTH-002 and BTH-004, produced an exceedance of the first benthic invertebrate threshold in 2014, such that they had sequential PMA-Analysis "Impact " determinations. The cause of these determinations is not clear at this point in time. Three stations, stations BTH-001, BTH-003, and BTH-005, exceeded the third benthic invertebrate threshold in 2014, such that EPT richness declined by 50% compared to the average of the previous two years. EPT richness also decreased at BTH-002 and BTH-004 but not enough to result in an exceedance. There appears to be a trend of decreasing EPT richness across the five benthic monitoring stations since 2008 and 2009 when EPT richness was highest. Possible reasons for the decreasing trend in EPT richness include the drought conditions in 2012, and the continuous discharge from SWM Pond 4 beginning in late 2011. However, assessing the results by station does not make a clear or consistent connection with SWM Pond 4. It is not clear why this trend has continued in 2014.

Two fish monitoring stations experienced a threshold exceedance in 2014. Two stations, EMS-003 and EMS-004, exhibited a 50% reduction in the number of fish captured. This is not of concern for either station. Station EMS-003 has low numbers and is prone to this exceedance with small changes in numbers of fish captured. Station EMS-004 had an unusually high number of fish in 2013, and the 2014 results represent a return to more typical numbers.

Multiple vegetation plots had threshold exceedances in 2014. The threshold exceedances are easily explained and not of immediate concern. The threshold for herbaceous cover was exceeded positively in Plots 2 and 8, and negatively at Plots 1 and 3. Plot 1 was affected by standing water when monitored, but the vegetation is suited to hydric soils and is not expected to be adversely affected. Plot 3 is in the process of recovering to pre-construction levels of herbaceous cover.

Herbaceous species diversity positively exceeded the pre-construction threshold in both Plots 2 and 6, while Plots 5 and 7 both fell below the threshold. Plot 5 has a low number of species, and is susceptible to a threshold exceedance due to small changes. Plot 7, while below the threshold, remains one of the most diverse vegetation plots. The hummocky terrain results in varied species composition from one area to another within the plot, and a slight shift in the location of sub-plots can affect results. The exceedance is not cause for immediate concern.

The canopy cover at Plot 8 continued to be below the threshold based on pre-construction cover, and is still anticipated to recover from construction of the crossing of Hanlon Creek Boulevard over Tributary A.

Although Coefficient of Wetness (CW) is not used as a specific threshold for the vegetation monitoring, it is noteworthy that the CW values have shown a drying trend between 2011 and 2014 at Plots 16 and 18. These plots are located in close proximity to recent development (Block 9 and Block 10) and Hanlon Creek Boulevard. It appears that fluctuations in groundwater levels would have little to no effect on the soil wetness in the wetlands because their elevations have never been above the ground surface of the wetlands. Groundwater levels in the vicinity of Plots 16 and 18 do not show a trend that matches the declining trend in CW values. However, ponded surface water in the plot may be drying up earlier. Monitoring of vegetation and groundwater should continue at these plots in order to determine whether there is a relationship between groundwater and the CW values. In addition, the presence and depth of surface water should be monitored in some manner each spring.

An associated threshold exceedance is the decline in amphibian abundance at three stations in 2014. A decrease of two calling codes was observed for Gray Tree Frog in Plots 7 and 16, Spring Peeper in Plot 6, and Wood Frog in Plots 6 and 16. The overall results for the first two species reflect data gathered in 2013 and abundance for both has remained relatively consistent since 2006. Wood frog numbers seem to alternate years of high abundance with years of low abundance. The reduction in seasonal standing water within the central portion of the swamp has undoubtedly made the Plot less suitable for anuran breeding, and the addition of surface water monitoring at Plot 16 may help to explain the changes in anuran calling at that location.

Thresholds were reached for breeding bird species diversity and breeding bird abundance. In 2014, Plots 3, 6 and 9 were just below the species-diversity threshold, while Plot 5 was well below the threshold. Plots 3, 5 and 9 are well removed from construction, and the change is attributed to natural variation. Plot 6 was near the construction at Block 14. If there was an effect from construction activity, it is expected to have been temporary.

Plots 3, 4, 5, 6, 7 and 9 were all below the threshold for breeding bird abundances in 2014. None of these are of immediate concern. Overall, the 2014 data strongly reflects a year of lower-than-average bird diversity and abundance, and annual fluctuations are expected.

Corrective Measures Undertaken

No corrective measures were undertaken in 2014. The RAAP group met on one occasion regarding a temperature exceedance that resulted from a faulty data logger.

The temperature effects continued at SWM Pond 4, and the corrective measures undertaken in 2012 were again monitored for effectiveness in 2014. The corrective measures undertaken in 2012 included:

1) raising the outlet of the cooling trench at Pond 4 (removed in early 2013),
2) raising the weir level at the pond outlet at Pond 4, and
3) planting of aquatic vegetation throughout the shallow areas of the pond as well as planting vines and herbaceous species in and around the cooling trench at Pond 4.

The decision to wait on implementing additional corrective measures was based on the fact that the vegetation planted in 2012 can take several years (5+) to become well established and mature in order to function as intended. Looking ahead, it may be necessary to undertake additional corrective measures to address the thermal impacts from SWM Pond 4.

While other issues have been identified through review of the monitoring results, there were no other clear cause-and-effect relationships that constituted problems to be rectified through corrective measures.

Recommendations

Based on the 2014 monitoring results, it is recommended that additional corrective measures be developed to address the effects of SWM Pond 4 on water temperatures in Tributary A. This may be an extension of vegetation-planting measures already taken, or new measures.

The need for additional monitoring requirements should be considered in conjunction with the development and implementation of the corrective measures.

It is also recommended that existing monitoring continue with diligent attention given to stream temperatures and the SWM Pond 4 mitigation measures put in place to date, using the RAAP as prompted by any stream temperature or turbidity exceedances.

As a new monitoring item, surface water should be monitored at Plots 16 and 18 and adjacent roads, swales and development blocks in order to determine whether surface hydrology has been altered in a manner that is affecting Plots 16 and 18.

The frequency of terrestrial monitoring should be reviewed to determine if some or all of the plots should be monitored at a reduced frequency.

Along with the above recommendations, the groundwater, surface water, fish, benthic invertebrate, vegetation, breeding bird and amphibian monitoring should continue in 2015 as per the Standard Operating Procedures for the Consolidated Monitoring Program (NRSI 2010).

Conclusions

Monitoring at the Hanlon Creek Business Park in 2014 was successful in providing useful information to describe environmental conditions on site, detect issues and develop solutions.

Elevated stream temperatures and the contributing temperature impacts from SWM Pond 4 continued to be the most prominent issue in 2014. As such, monitoring in 2015 should give particular attention to this issue through the continued monitoring of nearby wells and the effectiveness of the planted vines and aquatic vegetation. The RAAP group should carefully review any stream temperature threshold exceedances. Additional corrective measures should also be developed to mitigate the effects on stream temperatures, including additional monitoring as required to inform such measures.

The decline in CW at vegetation Plots 16 and 18 represents another issue to be investigated further, and surface water monitoring at these plots should be implemented.

1.0 Introduction

The monitoring program associated with the Hanlon Creek Business Park (HCBP) is an integration of a series of monitoring requirements arising from recommendations made in the Consolidated Environmental Impact Study (NRSI 2004), the Draft Plan Conditions (OMB 2006), and review comments from agencies during the various stages of the planning process. A consolidation of the monitoring on the HCBP Lands was required as a condition of approval of the *HCBP Environmental Implementation Report 2009* (EIR) prepared by Natural Resource Solutions Inc. (NRSI 2009). The City of Guelph Environmental Advisory Committee (EAC) recommended approval of the EIR, with a list of conditions that should be met prior to registration of the plans for Phases 1 and 2. Condition 8 states:

> *That a comprehensive and consolidated monitoring program, which specifies frequency, location, protocols, timing, thresholds, and specific contingency measures be submitted and approved by the City of Guelph and the GRCA [Grand River Conservation Authority].*

To meet the above condition, a document titled *Hanlon Creek Business Park Consolidated Monitoring Program* (NRSI 2010) was created as a reference document containing the standards that are to be followed in carrying out the Consolidated Monitoring Program. Refer to that document for detailed information on the framework of the monitoring program and the Standard Operating Procedures for each monitoring component. The Standard Operating Procedures provide detailed methodologies such that the performance monitoring can be carried out consistently over the years of monitoring.

A consolidation of the monitoring on the Hanlon Creek Business Park (HCBP) Lands is required as a condition of approval of the *HCBP Environmental Implementation Report 2009* (EIR) prepared by Natural Resource Solutions Inc. Standard Operating Procedures for this monitoring can be found in a report titled *Hanlon Creek Business Park Consolidated Monitoring Program*, prepared by NRSI in 2010.

Pre-construction monitoring began in 2006 and continued for 4 years. Construction-phase monitoring began in 2010. Monitoring occurs either at specific times of the year, and certain components of groundwater and surface water occur year round. Annual reporting occurs according to the calendar year. A Rapid Assessment and Action Protocol (RAAP) is in place to address immediate monitoring concerns, with a focus on surface water temperature and turbidity.

This report integrates the information from all monitoring components for the 2014 calendar year. In 2010, pre-grading and servicing activities began within Phase 1 of the Hanlon Creek Business Park. Phase 2 pre-grading and servicing began in 2011. Building and site construction on individual blocks commenced following completion of servicing, and has continued in 2014. Construction-phase monitoring began in 2010 following four years of pre-construction monitoring.

Individual reports from each discipline are appended, and the results are summarized in Section 2.0. The consolidated reporting began in 2009. Natural Resource Solutions Inc. (NRSI) has prepared this consolidated report each year with support from Banks Groundwater Engineering Limited (hydrogeology), and AECOM (surface water).

1.1 Study Area

The Hanlon Creek Business Park comprises the lands between Downey Road and the Hanlon Expressway, and between Forestell Road and the south end of the Kortright subdivision along Teal Drive (Map 1). Prior to development, lands within Phases 1 and 2 were a mix of agricultural fields, meadow, woodland, forest and Provincially Significant Wetlands (PSW) consisting of swamp, marsh and thicket, while Phase 3 was primarily agricultural field and cultural meadow, with small wetlands. The core area of natural features was designated as natural heritage lands to be retained in their pre-development state. The agricultural fields and associated hedgerows, and small isolated habitats were designated for roads and development blocks.

The creek, wetlands and forested uplands in the HCBP are part of the much larger Hanlon Creek watershed. The central wetlands in the HCBP are part of the Hanlon Swamp Wetland Complex and therefore are considered provincially significant. In addition, a small wetland in the southwestern portion of the HCBP, next to Downey Road, is part of the provincially significant Speed River Wetland Complex.

This area encompasses a headwater tributary of Hanlon Creek. The tributary within the HCBP was designated as Tributary A in the Hanlon Creek Watershed Study (Marshall Macklin Monaghan Limited 1993). All of Hanlon Creek is designated as a cold-water stream to be managed for Brook Trout (*Salvelinus fontinalis*) (GRCA and MNR 1998).

1.1.1 Construction Activity

Construction commenced in late 2009 and has continued each year through to 2014. Construction activity in 2014 within Phases 1 and 2 is outlined below and highlighted on Map 2.

<u>Phase 1, Stage 3</u>

- Operation of commercial building I – Part of Block 5 – 500 Hanlon Creek Boulevard
- Operation of industrial building – Part of Block 9 – 345 Hanlon Creek Boulevard
- Operation of industrial building – Part of Block 10 – 265 & 285 Hanlon Creek Boulevard
- Construction of building – Part of Block 14 – 230 Hanlon Creek Boulevard

<u>Phase 2</u>

- Preliminary grading of Blocks 8, 9 and 26
- Laird Road overpass was in use in 2014

No construction activity occurred within Phase 1 (Stage 2) or Phase 3 in 2014.

1.2 Monitoring Requirements and Components

A total of seven discrete monitoring requirements were identified during the planning process for the HCBP. The requirements are each rooted in one or more of the various stages of the process, including the Consolidated EIS (NRSI 2004), the Draft Plan Conditions (OMB 2006), the Environmental Implementation Report, and review comments from agencies pertaining to the design, mitigation and restoration of features in the Business Park.

The seven discrete monitoring requirements are as follows:

1. **Performance of Stormwater Management Systems:** Monitoring of hydrogeology, creek flows and temperatures, aquatic biota and wetlands, arising from the Draft Plan Condition #12 to provide baseline information on interactions and as input to the design of stormwater management facilities that discharge to Tributary A, as well as post construction monitoring of performance of the ponds (especially thermal impacts).
2. **Groundwater and Wetlands for the HCBP:** Monitoring arising from the Draft Plan Condition #12 of hydrogeology and wetlands at strategic locations to provide baseline information on spatial distribution and interactions of groundwater/wetlands such that block-level infiltration targets can be assessed.
3. **Groundwater and Wetlands for the Mast-Snyder Gravel Pit:** Monitoring of hydrogeology and wetlands in the western portion of lands south of Laird Road (Speed River PSW) to monitor changes in groundwater and wetlands stemming from concerns over potential impacts of the proposed neighbouring Mast-Snyder Gravel Pit.
4. **Permit Conditions and EIR Recommendations:** Monitoring arising as conditions from permit applications/review as well as impact predictions specifically arising from recommendations out of the EIR process.
5. **Success and Naturalization of Restoration Areas:** Monitoring of success and naturalization processes of restoration areas within buffers, swales and stormwater management areas, arising from agency comments and restoration planting warranty.
6. **Wildlife Movement:** Monitoring of wildlife movement throughout the Business Park, with a focus on movement and mortality associated with Laird Road and Hanlon Creek Boulevard (Road 'A').
7. **Construction Monitoring:** Monitoring arising from the Draft Plan Condition #10, which states that an environmental inspector is to carry out the construction monitoring during grading, servicing, and building construction.

There are eight performance monitoring components and two construction monitoring components that occur on the HCBP property, and they are being conducted to serve one or more of the requirements listed above. Pre-construction performance monitoring occurred over a number of years to establish baseline conditions. Most of the monitoring activities have been in effect annually beginning in 2006. Groundwater monitoring began in 1999. Some construction inspection occurred in 2009 associated with the Road 'A' culvert directional service installation under the Hanlon Expressway, and borrow pit operations in the southeast corner of the Business Park. In 2010, construction-phase monitoring began which included the monitoring of grading and servicing construction activities.

The City of Guelph, as the developer representative, is responsible for this monitoring. The duration of the responsibility to monitor has been defined for each of Phases 1 and 2 as the time when 75% of the area of the individual phase is built, plus an additional two years. It is anticipated that this timeframe will also apply to Phase 3.

1.2.1 Performance Monitoring

The performance monitoring components are indicated as follows, with the past years of monitoring indicated in parentheses.

- Groundwater (most years from 1999 to 2014)
- Stream Temperature and Flow (annually from 2006 to 2014)
- Fish (annually from 2006 to 2014)
- Benthic Invertebrates (annually from 2006 to 2014)
- Vegetation and Soils (annually from 2006 to 2014)
- Breeding Birds (annually from 2006 to 2014)
- Amphibians (annually from 2006 to 2014)
- Salamanders (2009 and 2010 only)

1.2.2 Construction Monitoring

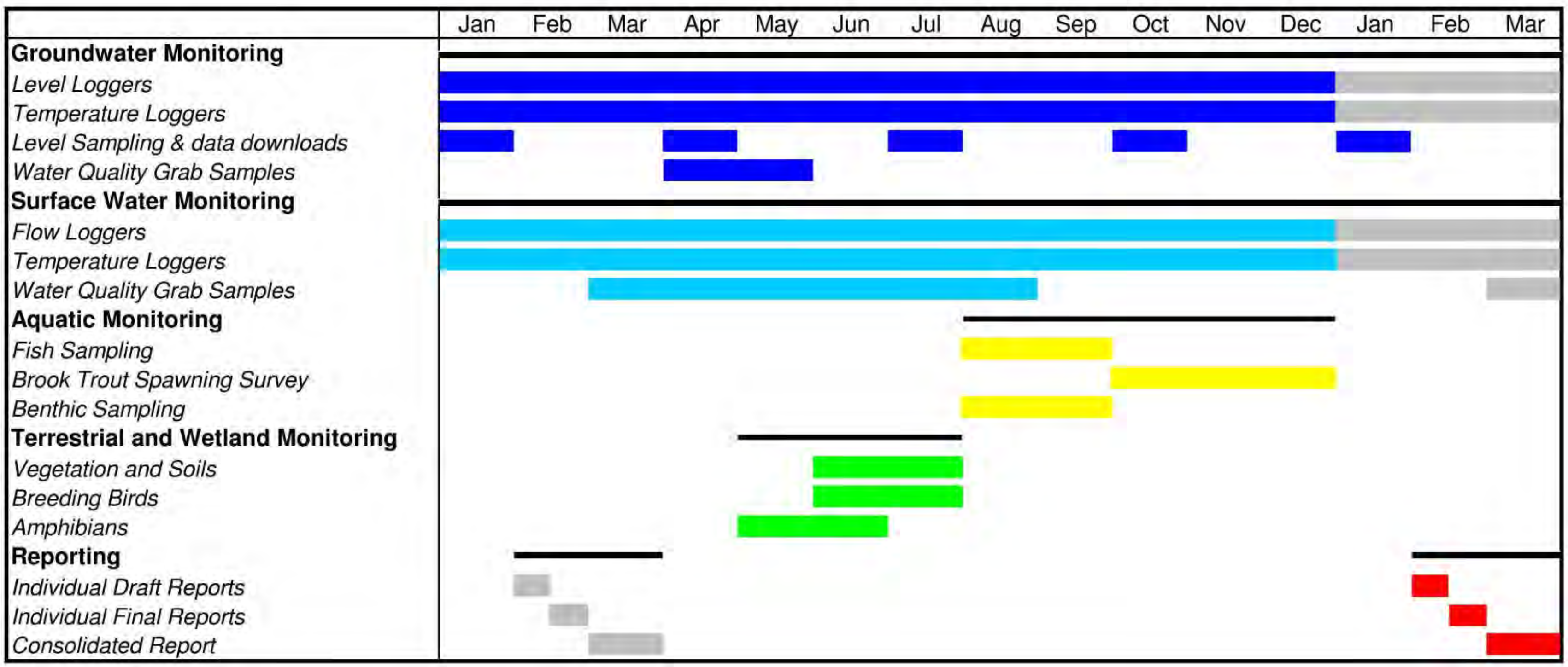
Construction monitoring is tied to the specific undertaking. Generally, construction monitoring must occur to ensure compliance with the conditions of various permits, including permit(s) from the Grand River Conservation Authority (GRCA) under Ontario Regulation 150/06 and the Letter of Advice from GRCA that constitutes approval under Section 35 of the *Fisheries Act*. Construction monitoring also serves as a means to avoid contravention of other regulations, such as Section 36 of the federal *Fisheries Act* pertaining to deleterious substances. In the specific case of the HCBP, the need for construction monitoring also stems from Condition 10 from the Ontario Municipal Board (OMB) hearing for the HCBP Draft Plan (June 2006). The condition states that an environmental inspector is to carry out the construction monitoring during grading, servicing, and building construction.

Construction inspection reports from 2014 are found in Appendix I.

1.3 Annual Schedule of Activities

Table 1 provides the general annual timeline of performance monitoring activities, which approximates the schedule of the 2014 monitoring. The specific dates of monitoring activities in 2014 are provided in the appended individual reports. Each colour represents an individual monitoring component (Groundwater Monitoring – dark blue, Surface Water Monitoring – light blue, Aquatic Monitoring – yellow, Terrestrial and Wetland Monitoring – green). The timeline for Reporting is represented by red.

Table 1. General Annual Schedule of Performance Monitoring Activities



2.0 Monitoring Results

2.1 Climate Data

Climate data provided by the Region of Waterloo International Airport Station (WMO ID 71368) was utilized for groundwater monitoring due to its proximity to the HCBP site and availability of total daily precipitation maximum daily air temperature data. For assessment of surface water monitoring data, climate information was used from the Guelph Turfgrass Institute and the Elora Research Station, provided by the University of Guelph.

The precipitation is important for reporting and interpreting both the groundwater and surface water monitoring results. This includes trends preceding the monitoring year, and patterns during the monitoring year.

From 2003 to 2014, there has generally been lower-than-normal precipitation resulting in a cumulative negative departure from monthly normals. Fluctuations have occurred during this time, including an increase in early 2014, but the overall trend is a negative departure from normal. This does not necessarily translate into analogous reductions in groundwater or streamflow. Instead, groundwater levels are strongly correlated with precipitation during the previous 18 months. During the same period, cumulative departure from the average of the preceding 18-months illustrates periods of decrease and increase in precipitation. The year 2007 stands out as a year of substantial decrease in precipitation, followed by an increase in precipitation from mid-2008 to mid-2009. Smaller fluctuations have occurred since that time, including the year 2014 that had both decreasing and increasing trends within the year.

Precipitation in 2014 was below normal. At the Elora Research Station, total precipitation for 2014 was 776.7mm, compared to a normal of 923.3mm known for the Guelph Arboretum. At the Region of Waterloo International Airport Station, total precipitation in 2014 was about 826mm, compared to a 44-year average of about 883mm.

Substantial variation in precipitation occurred during 2014, beginning with below-normal precipitation for January to March. Precipitation was above normal in April, then well below normal in May and June, and then well above normal in July. A dry period in August resulted in precipitation that was well below normal. Then in September there was double the normal precipitation, followed by a normal amount of precipitation in October. The year ended with precipitation well below normal in November and December. Altogether, total precipitation was above normal for the months of April, July, and September, and below normal for the other nine months.

The air temperatures from May to September were generally cool to normal. July and August average air temperatures in 2014 were lower than Canadian Climate Normals from 1971 to 2000 at the Guelph Arboretum. They were also among the cooler average air temperatures documented during the monitoring period since 2007. Average air temperatures were normal in May and September. A notable exception to these cool to normal temperatures was June, which had average temperatures above normal.

2.2 Groundwater Levels and Flow

During the 2014 monitoring period there were 37 functioning monitoring wells and 19 mini-piezometers located across the HCBP site. Two of the mini-piezometers were installed in June 2013 to provide additional monitoring data related to the effects of stormwater management (SWM) Pond 4 on Tributary A, and they remained in place in 2014. To evaluate the response to spring thaw and precipitation at selected groundwater monitors, data loggers were installed to record groundwater levels on a more frequent basis, with installation at some stations beginning in 2007. In the year 2014, groundwater elevations were recorded using data loggers in 38 of the 56 groundwater monitoring stations. Table 1 in the groundwater technical memorandum prepared by Banks Groundwater Engineering Limited (Appendix II) lists the monitoring wells and mini-piezometers where the 38 data loggers were in operation for all or part of 2014. In addition, groundwater quality samples were collected from a total of 36 monitoring wells that were available for sampling in 2014. These were the same wells that were sampled in 2013. The locations of the groundwater monitoring stations are shown on Map 3 including new, existing, proposed, and abandoned stations as of December 2013.

The resulting groundwater level monitoring data is tabulated and plotted on graphs in the appendices of the groundwater technical memorandum prepared by Banks Groundwater Engineering Limited (Appendix II). Those results are summarized and discussed below.

Long-Term and Medium-Term Observations of Groundwater Levels

Groundwater levels are interpreted to have been elevated in the early to mid-1990s, followed by a decline from 1997 to 2007. These trends are based on climate data beginning in 1971. On-site groundwater monitoring began in 2003, and since that time precipitation has generally continued to decline.

In 2007, the effects of below-average precipitation were expressed in groundwater levels in July and November, when precipitation was the lowest observed from 1971 to 2014.

In late 2010 and early 2011, groundwater levels declined and approached the low levels observed in 2007. This is attributable to below-average annual precipitation in late 2009, through most of 2010, and into February 2011.

In 2012, groundwater levels at many monitored locations on-site during the summer and fall were the lowest recorded since monitoring began in 2003. The total precipitation in 2012 was 684 mm, which was the fourth lowest recorded amount from 1971 to 2014.

The periods of low groundwater levels are contrasted by higher levels during the intervening periods. Annual precipitation in 2003, 2006, 2008, 2011, and 2013 was above average. This appears to have influenced groundwater levels in the spring of 2004 and 2007, the spring and fall of 2008, in the last five months of 2011, and from spring to fall in 2013.

General Observations in 2014

In 2014, groundwater levels are easily explained by the weather including the patterns of precipitation throughout the year. The highest groundwater levels observed in monitors equipped with data loggers occurred during the months of January, April, September, and November. The high levels in January occurred in response to melting snow pack and rainfall events while maximum daily temperatures were above freezing; thus, the high levels occurred in spite of the below-normal winter precipitation. The high levels in April were in response to above-average precipitation combined with the spring melt. In September, high levels were in response to double the normal amount of precipitation. An increase in November groundwater levels occurred after precipitation events greater than 15mm in October and November. Although total precipitation in November was not particularly high, such precipitation events can lead to increases in groundwater levels.

The lowest groundwater levels occurred in early March, early September and early November. These periods of low levels were considered normal, as groundwater elevations at all monitoring stations remained within the normal range throughout 2014.

Site-Wide Patterns in 2014

The groundwater elevation data from the 38 groundwater monitoring stations throughout 2014 continued to exhibit the downward hydraulic gradients (i.e. groundwater recharge conditions) in the upland portions of the site, and upward hydraulic gradients in the vicinity of, and within, the core wetland complex (i.e. groundwater discharge conditions). Groundwater discharge conditions have also been confirmed at the Downey Road PSW.

The greatest range in groundwater elevations occurred around the perimeter locations of the site where groundwater recharge to the medium- to coarse-grained deposits is most significant. The smallest fluctuations occurred in and adjacent to the core wetland and Hanlon Creek Tributary ‘A’. Shallow depths to groundwater and the occurrence of groundwater discharge to these surface water features naturally limit the range of groundwater elevations in these areas.

Graphs illustrating hydraulic gradients and groundwater elevations are included in the groundwater technical memorandum prepared by Banks Groundwater Engineering Limited (Appendix II).

2014 Monitoring of Groundwater Levels in the Core PSW

Groundwater levels in 2014 were monitored at 14 monitoring wells and 10 mini-piezometer stations within or near the Core PSW (Table 2, Map 3).

Table 2. Monitoring Wells and Mini-Piezometers Within or Near the Core PSW

Monitoring Wells		Mini-Piezometers	
MW103	MW119A	PZ-1	PZ-12
MW104	MW121A	PZ-2	PZ-13
MW105	MW122A	PZ-4	PZ-14
MW111	MW127	PZ-7	
MW116A	MW129	PZ-8	
MW117A	MW130A	PZ-10	
MW118A	MW131	PZ-11	

In 2014, the observed groundwater levels and temperatures in the monitoring wells and mini-piezometers responded to precipitation and maximum daily air temperatures. This confirms the inherent relationship of the wetlands to the shallow groundwater system. The hourly recording of groundwater levels at mini-piezometer locations also indicates subtle fluctuations during each 24-hour period, likely associated with diurnal cycles of evapotranspiration in the wetland. While responsiveness is apparent, the range of groundwater levels in mini-piezometers is more subdued than in those at other locations on the HCBP site. This reflects the relatively constant groundwater elevations in the wetland area, usually with only minor perturbations observed relative to precipitation and/or temperature changes.

During the months of January, February and March, groundwater levels at Core PSW monitoring stations were within the typical range for this time of year, fluctuating in direct response to maximum daily temperatures above 0°C and corresponding periods of infiltrating precipitation. The combined snowfall and rain through January, February and March was equivalent to about 102 mm of precipitation, which is about 80 mm below the normal amount for this three-month period. However, the brief thaws in January and February caused groundwater levels to rise.

Groundwater levels began a gradual decline in mid-May, with occasional short-duration increases in response to precipitation events measuring more than 15 mm in a 24-hour period. The lowest levels observed in 2014 varied from location to location, but most occurred during late-August and early-September. At almost all locations where data loggers had been in place for more than three years, the 2014 summer levels were comparable to 2013 summer levels, which were above the low levels observed during the drought in the summer of 2012. At many Core PSW monitoring stations, groundwater levels rose in response to precipitation in early-September and again in October.

Groundwater levels in the three mini-piezometer monitoring locations (i.e. from north to south PZ-4D, PZ-2D, and PZ-1D) that are located in the Core PSW, were below the normal range for most of 2012. During 2013 and 2014, groundwater levels were within the range of previous years. Groundwater levels were typically at, or above, ground level during spring months and reduced levels during late-summer months.

Similarly, groundwater levels recorded in streambed mini-piezometers (i.e. from north to south PZ-10, PZ-8, PZ-11, and PZ-7) were below the level of the creek and the streambed for part, if not most, of 2012. Groundwater levels during 2013 and 2014 were within the range observed in previous years, where data is available. The recorded groundwater elevations were at, or above, the streambed during spring months and reduced levels during late-summer months.

Climate had the greatest, if not only, influence on groundwater levels within the Core PSW in 2014. There were no apparent short-term and/or longer-term changes in groundwater levels that could be attributed to construction activities during 2014 within the HCBP. As of the end of 2014, five lots in Phase 1 had been developed and another six were at various stages of development. The remainder of the graded portion of the site consisted of paved roadways, vegetated stormwater management swales and ponds, gravel-surfaced trails, and barren soils across most vacant lots. Based on the observed responses of groundwater levels to rainfall events and above-normal total monthly precipitation during April, July, and September, it is evident that infiltration was occurring across the site.

<u>2014 Monitoring of Groundwater Levels in the Downey Road PSW</u>

Groundwater levels in 2014 were monitored at two stations at the Downey Road PSW. These include monitoring well MW003, which is located on the north edge of the PSW, and mini-piezometer nest PZ-9, which is located in the centre of the PSW (Map 3).

During the months of January, February and March 2014, groundwater levels and temperatures were within the typical range for this time of year, fluctuating in direct response to maximum daily temperatures above 0°C and corresponding periods of infiltrating precipitation. As noted previously, the combined snowfall and rain through January, February and March was equivalent to about 102 mm of precipitation, which is about 80 mm below the normal amount for this three-month period. However, the brief thaws in January and February caused groundwater levels to rise to within about 20 cm of the highest observed at this location. Groundwater levels began a gradual decline in mid-May, with occasional short-duration increases in response to precipitation events measuring more than 15 mm in a 24-hour period. Groundwater levels rose in response to precipitation in early-September and again in October.

The responses to precipitation events and spring thaw, or lack thereof, observed in this monitor during the period 2007 to 2014, have demonstrated the local sensitivity of the shallow groundwater system, which is associated with the coarse-grained nature of the overburden deposits within and above the uppermost aquifer. The below-normal precipitation during 2014 had a negligible effect on groundwater levels at this location.

It is noted that responses to precipitation and temperature are apparent in PZ-9D in Graph F2, similar to MW003, confirming the infiltrative capacity of the medium- to coarse-grained deposits on this site and the inherent relationship of the wetlands to the shallow groundwater system. Each year, groundwater levels decline to an elevation that is below ground level in the wetland, typically during June or July.

A small upward hydraulic gradient is also evident at various times when groundwater levels in MW003 are higher when compared with levels in the adjacent PZ-9D.

2014 Monitoring at Perimeter Locations

Groundwater levels in 2014 were monitored at nine monitoring wells around the perimeter of the site. These included stations MW125, MW126, MW128, MW124, MW107, MW132, MW135, MW133, and MW134 (Map 3).

Groundwater elevations vary more widely over the year at perimeter locations in comparison to the Core PSW locations. The perimeter groundwater monitoring stations responded to the above-normal precipitation during April, July, and September 2014, similar to the monitoring stations described in the previous two sections. There were no apparent short-term and/or longer-term changes in groundwater levels at perimeter monitoring stations that could be attributed to construction activities during 2014 within the HCBP.

2.3 Surface Water Levels and Flow

As part of the surface water monitoring program in 2014, water depth (level) was measured at 10 stations on Tributary A and Tributary A1. The station names are HC-A: 03, 04, 06, 08, 09, 10, 11, 12, 13 and 14. In addition, one station (SR1-1) was located on an unnamed tributary on the west side of Downey Road across from the Downey Road PSW. Flow rating curves were developed to provide continuous flow data. In addition to the continuous flow monitoring, baseflow measurements were taken at eight stations on Tributary A between August and December, 2014. The resulting surface water data is presented in the tables and figures in the surface water monitoring report prepared by AECOM (Appendix III). Those results are summarized and discussed below.

As per GRCA requirements, monitoring was also completed at each of the stormwater management facilities, which included SWM ponds 1, 2, and 4. Monitoring of these locations included three components: inflow and discharge flow rates, water temperature, and water quality sampling. Inflow and discharge are discussed below while water temperature and water quality are discussed in Sections 2.4 and 2.5, respectively. Inflow and discharge flow rates were computed based on water level loggers placed in each facility's inlet and outlet structures. The locations of loggers within each SWM Pond are provided in Table 2. Refer to Figure 4 for all monitoring station locations.

Table 3. Stormwater Management Pond Monitoring Stations

Station	Data Collected	Date installed	Location
Pond 1			
HC-P1(01)	Temperature	September 2011	In pond close to bottom
HC-P1(02)	Temperature	September 2011	In pond near mid-depth
HC-P1(03)	Temperature	September 2011	In pond at surface
HC-P1(04)	Temperature, Depth	September 2011	Inlet
HC-P1(05)	Temperature, Depth	September 2011	Inlet
HC-P1(06)	Temperature, Depth	June 2011	Outlet
HC-P1(07)	Temperature	June 2011	Cooling trench outlet
HC-P1(08)	Temperature	June 2011	Cooling trench outlet
Pond 2			
HC-P2(01)	Temperature	April 2011	In pond close to bottom
HC-P2(02)	Temperature	April 2011	In pond near mid-depth
HC-P2(03)	Temperature	April 2011	In pond at surface
HC-P2(04)	Temperature, Depth	April 2011	Inlet
HC-P2(05)	Temperature, Depth	August 2012	Inlet
HC-P2(06)	Temperature, Depth	June 2011	Inlet
HC-P2(07)	Temperature, Depth	April 2011	Outlet
Pond 4			
HC-P4(01)	Temperature	October 2011	In pond close to bottom
HC-P4(02)	Temperature	November 2011	In pond near mid-depth
HC-P4(03)	Temperature	November 2011	In pond at surface
HC-P4(04)	Temperature, Depth	August 2012	Inlet
HC-P4(05)	Temperature, Depth	October 2011	Outlet
HC-P4(06)	Temperature	October 2011	Cooling trench outlet

Operational issues were experienced in 2014 at several surface water monitoring stations. A faulty shuttle caused numerous errors in some of the continuous monitoring equipment. The equipment went missing numerous times at HC-P1(06) in early 2014. Replacement was eventually discontinued and no data was collected at that station in 2014. The resulting data gaps in logger files are given in detail in the surface water monitoring report prepared by AECOM (Appendix III).

A plot showing the creek flow at eight surface water stations as well as precipitation data collected at the Guelph Turfgrass Institute for the 2014 monitoring period is shown in Figure 1. Baseflow measurements for 2014 are shown in Figure 2, and a summary of baseflow monitoring from 2008 to 2014 is provided in Table 4.

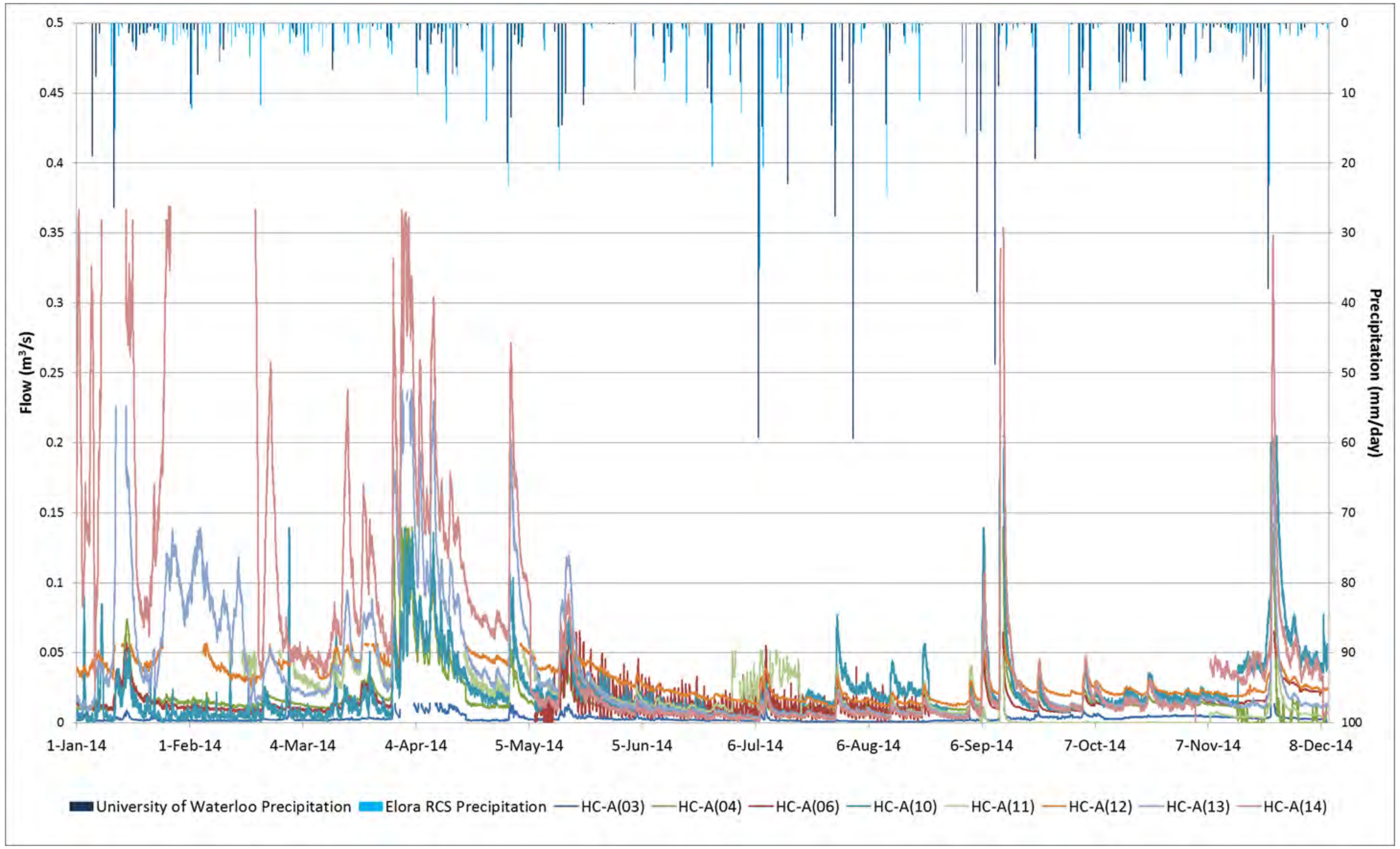


Figure 1. Tributary A and A1 Flow and Precipitation Monitoring – Continuous for Eight Stations, January 2012 to December 2014

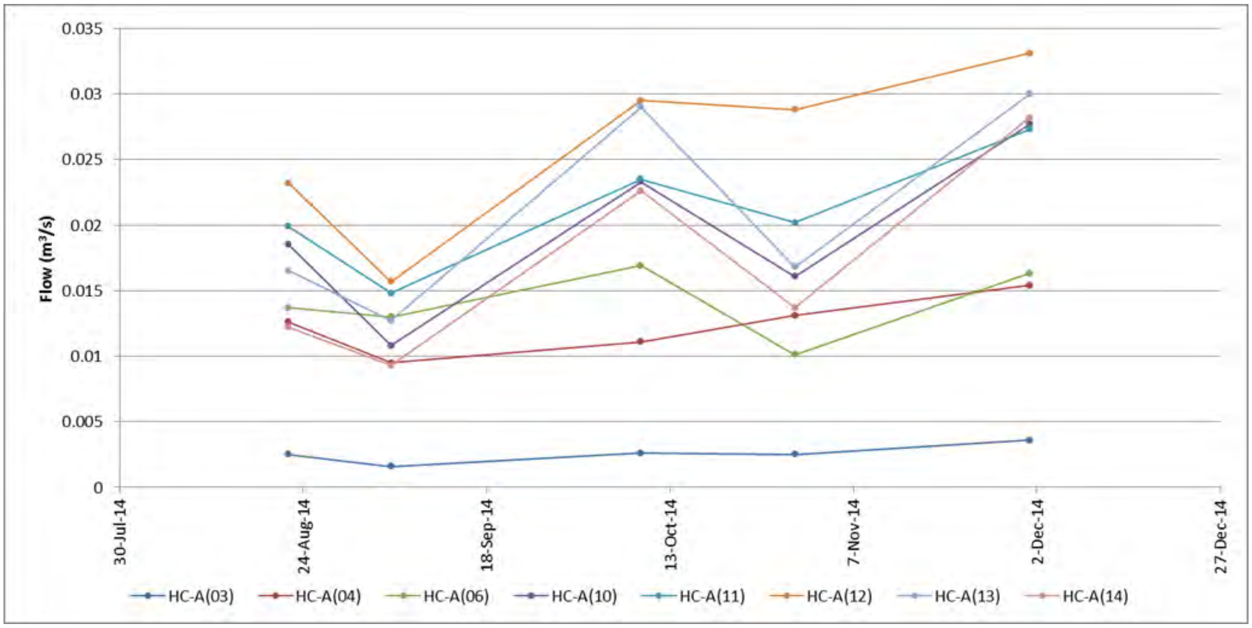


Figure 2. 2014 Hanlon Creek Tributary A Baseflow Measurements

Table 4. Hanlon Creek Baseflow Monitoring – 2008 to 2014 Summary (L/s)

Station	HC-A(03)	HC-A(04)	HC-A(06)	HC-A(08) Tributary	HC-A(09)	HC-A(10)	HC-A(11)	HC-A(12)	HC-A(13)	HC-A(14)
2008 Min	n/a	3.5	2.7	2.1	3.8	7.7	n/a	n/a	n/a	0.9
2009 Min	n/a	3.9	1.2	3	4.2	5	n/a	n/a	n/a	1.8
2010 Min	n/a	0.4	0.4	-7.3	1.1	0.8	n/a	n/a	n/a	0.9
2011 Min[2]	2.8	5.5	0.8	1.5	n/a	2.4	4.6	5	2.8	1.5
2012 Min	0.11	3.2	3.1	0.5	n/a	1.3	0.7	1.71	0.61	0.71
2013 Min	1.2	8.2	5.5	n/a	n/a	6.4	2.7	12.5	3.4	3.4
2008 Max	n/a	11.3	10.7	10	9.4	16.8	n/a	n/a	n/a	12.1
2009 Max	n/a	14.9	25.6	22.1	18.7	56.3	n/a	n/a	n/a	53.8
2010 Max	n/a	2.9	4.9	12.3	6.7	22.2	n/a	n/a	n/a	11.2
2011 Max[2]	47.4	56.6	50	5.9	n/a	31.5	46	31.9	48.2	48
2012 Max	2.5	10.5	14.6	7.4	n/a	13.2	45.6	17.6	36.6	20.7
2013 Max	4.4	16.8	10.3	n/a	n/a	16.9	16	21.7	15.8	15.7
2008 Avg.	n/a	6	9.3	9	8.5	20.5	n/a	n/a	n/a	15.8
2009 Avg.	n/a	7.8	10.7	9.3	10.6	21.3	n/a	n/a	n/a	19.7
2010 Avg.	n/a	1.6	2	2.4	3.6	7.1	n/a	n/a	n/a	5
2011 Avg.[2]	14.6	21.7	20.2	2.7	n/a	19.3	20.6	18	20.5	17.2
2012 Avg.	1.1	6.1	7.5	3.1	n/a	8	14.4	10.6	10.9	9.1
2013 Avg.	2.7	11.2	7.9	n/a	n/a	10.4	10.4	16.1	8	9.9
2014 Avg.	2.6	12.3	14	n/a	n/a	19.3	21.1	26.1	21	17.2
Notes	[1] Hanlon Creek was noted to be dry or flows were below the measurement threshold flow at stations HC-A(03),HC-A(12), HC-A(13) and HC-A(14) [2] Baseflows were influenced by construction activities									

Baseflows in Tributary A in 2014 were greater than those in 2013 at seven of 10 stations. Only station HC-A(03), the farthest upstream in Tributary A, experienced lower baseflows in 2014 compared to 2013. The generally greater baseflows occurred in spite of total precipitation in 2014 (776.7mm at Elora Research Stn.) that was lower than in 2013 (885.8mm at Guelph Turf Grass Inst.). Precipitation in 2014 was also lower than the climate normal of 923.3mm for the years 1971 to 2000 at Guelph Arboretum.

The discharge from Pond 4 was observed to be near continuous again in 2014 causing elevated baseflow levels at HC-A(04), which is located a short distance downstream of Pond 4. The pond interacts with groundwater flowing in a northwesterly direction, and provides a more direct pathway for discharge to Tributary A. Some surface inflow was observed at the inlet to the pond, such that the recorded inflow was similar to the recorded outflow from the middle of May to the middle of August, 2014. There was some standing water at the inflow logger location in 2014. The depth of this standing water may have been augmented by vegetation growth at the inlet channel, affecting the calculation of flows. It remains the understanding that groundwater is the predominant source of the pond’s continuous discharge. The continuous discharge has resulted in the observed elevated baseflows in Tributary A, and has also affected summer water temperatures in Tributary A. The effect on water temperatures is discussed in Section 2.4.

Baseflow levels at station HC-A(04) were slightly higher than those at HC-A(06) in 2014. Prior to construction of Pond 4 in 2011, average baseflows from 2008 to 2010 ranged from 1.6 to 7.8 L/s at HC-A(04). In 2013 and 2014, average baseflows were 11.2 and 12.3 L/s (Table 4), reflecting the increase in baseflow that is attributed to continuous discharge of water from Pond 4.

The continuous discharge from Pond 4 has occurred since the construction of its outlet in 2011. Within that time, the average baseflows during the years 2011 and 2012 did not reflect the continuous discharge from Pond 4. Average baseflows at HC-A(04) were especially elevated during most of 2011 due to dewatering for the construction of the outlet and cooling trench for Pond 4, which was a unique condition for that year. In 2012 there were drought conditions, causing the average baseflows at HC-A(04) to be consistent with pre-2011 baseflows in spite of the continuous discharge that occurred that year. Without the continuous discharge, the baseflows in 2012 would have been much lower. Thus, the continuous discharge and resulting contribution to baseflows have been occurring for more than three years, beginning in late 2011 when construction of the cooling trench and outlet was completed.

Farther downstream, the reach between HC-A(09) and HC-A(10) receives input from a small groundwater-fed tributary (Tributary A1) that flows through a cedar-hardwood mixed, swamp which helped it remain a gaining reach. HC-A(10) and HC-A(11) have historically been groundwater discharge areas and this was the case for 2014. HC-A(12), HC-A(13) and HC-A(14) were all areas of ground water recharge or losing reaches again in 2014.

2.4 Water Temperature

2.4.1 Groundwater Temperature

Groundwater temperatures were recorded using data loggers in 38 groundwater monitoring stations across the Hanlon Creek Business Park during 2014. Temperature monitoring has been conducted since 2007 at four PSW monitoring locations (MW003, PZ-9D, PZ-2D, and PZ-7D), all of which are representative of shallow groundwater conditions within the site. The groundwater temperature results are given in the 2014 technical memorandum prepared by Banks Groundwater Engineering (Appendix II) and discussed as follows.

Temperature ranges for each location were as follows:

- MW003 – similar to previous years ranging from a low of 5.7°C in late-March to a high of 12°C in late-October
- PZ-9D – ranged from a low of 2.8°C in late-March to a high of 14.2°C in mid-September
- PZ-2D – ranged from a low of 3.9°C in mid-April to a high of 13.2°C in mid-September
- PZ-7D – ranged from a low of 4.8°C in early-March to a high of 11°C in late-August.

The temperature range of groundwater at greater depths in this general area tends to fluctuate in a narrower range, typically between 5 and 10°C. It is therefore apparent that the temperatures in the shallower groundwater regime in the vicinity of these four monitors are influenced by seasonal variations in air temperature and solar radiation. These data are interpreted to be representative of the temperature of groundwater discharging to the wetlands and creeks in these locations.

Monitoring well MW119A is located adjacent to and down-gradient from SWM Pond 4. Groundwater temperatures recorded in monitoring well MW119A during 2014 ranged from a low of 5.3°C at the start of April to a high of 14.7°C in mid-September. This is comparable to the ranges observed from 2008 to 2010. The high temperature of 14.7°C in 2014 was below the highest temperature recorded, which was 17.5°C on September 5, 2012. Prior to construction of SWM Pond 4 in late 2010, the highest groundwater temperature at this monitor was 15.0°C in early-September 2010. Prior to that, the years 2008 and 2009 had reached a maximum of approximately 13°C in September.

The bottom of SWM Pond 4 is below the shallow groundwater surface and as a result the un-lined pond is in direct contact with the local groundwater system. A portion of the water in the pond is interpreted to discharge from the pond as groundwater in a north-westerly direction, flowing into the ground adjacent to the pond. Therefore, water in the pond warmed by solar radiation during summer months of 2014 appears to have increased the groundwater temperature marginally in the area down-gradient (north-west) of the pond.

Additional monitoring of groundwater temperatures down-gradient of SWM Pond 4 was initiated in June 2013. A pair of shallow mini-piezometers (PZ-13 and PZ-14) were installed on the east and west banks of Tributary A and equipped with data loggers. The piezometers were located a short distance downstream from surface water monitoring station HC-A(04). Based on results from these monitoring stations it is apparent that the groundwater temperature at PZ-13D and PZ-14D, which reached a maximum of just less than 14°C in mid-September, was possibly influenced by the warmer shallow groundwater flow affected by Pond 4. Groundwater temperatures at PZ-13D and PZ-14D then returned to below those recorded in up-gradient MW131 by late-October in

2013 and 2014, reflecting the transition to colder weather and the greater responsiveness to air temperatures by the shallow mini-piezometers. This issue is discussed further in Section 5.1.2.

2.4.2 Surface Water Temperature

Surface water temperatures were measured in Tributary A and Tributary A1 using data loggers at 10 stream stations and in numerous locations within SWM Ponds 1, 2 and 4. The results are given in the surface water monitoring report prepared by AECOM (Appendix III), and are summarized and discussed as follows.

A plot of the continuous temperature monitoring throughout the year 2014 is provided in Figure 3. In the winter of 2014, stations HC-A(13) and HC-A(14) appear to have been at freezing (0°C) for most of the winter, indicating that the downstream portion of Tributary A was frozen. Stations HC-A(03), HC-A(09), and HC-A(10) demonstrated fluctuation in daily temperatures during winter months, at times with temperatures near or below freezing. Stations HC-A(04), HC-A(06), HC-A(08) and HC-A(11) also showed significant fluctuations, with temperatures remaining above freezing. Station HC-A(08) on Tributary A1 maintained the highest temperatures, generally above 3°C.

During summer months, stations HC-A(04) and HC-A(06), located downstream of the Pond 4 outlet, recorded high average temperatures and little daily fluctuation due to the influence of Pond 4's continuous discharge compared to HC-A(03) which is not impacted by pond discharge. Downstream stations which are more exposed such as HC-A(10), HC-A(12), HC-A(13) and HC-A(14); and those with a wider flow channel and shallower depths (HC-A(09)) show the highest daily variation in temperature as there is greater opportunity for solar radiation impact. Station HC-A(08) shows the lowest temperatures and daily temperature variation during the summer, indicating the presence of groundwater inputs in Tributary A1 where this station is located.

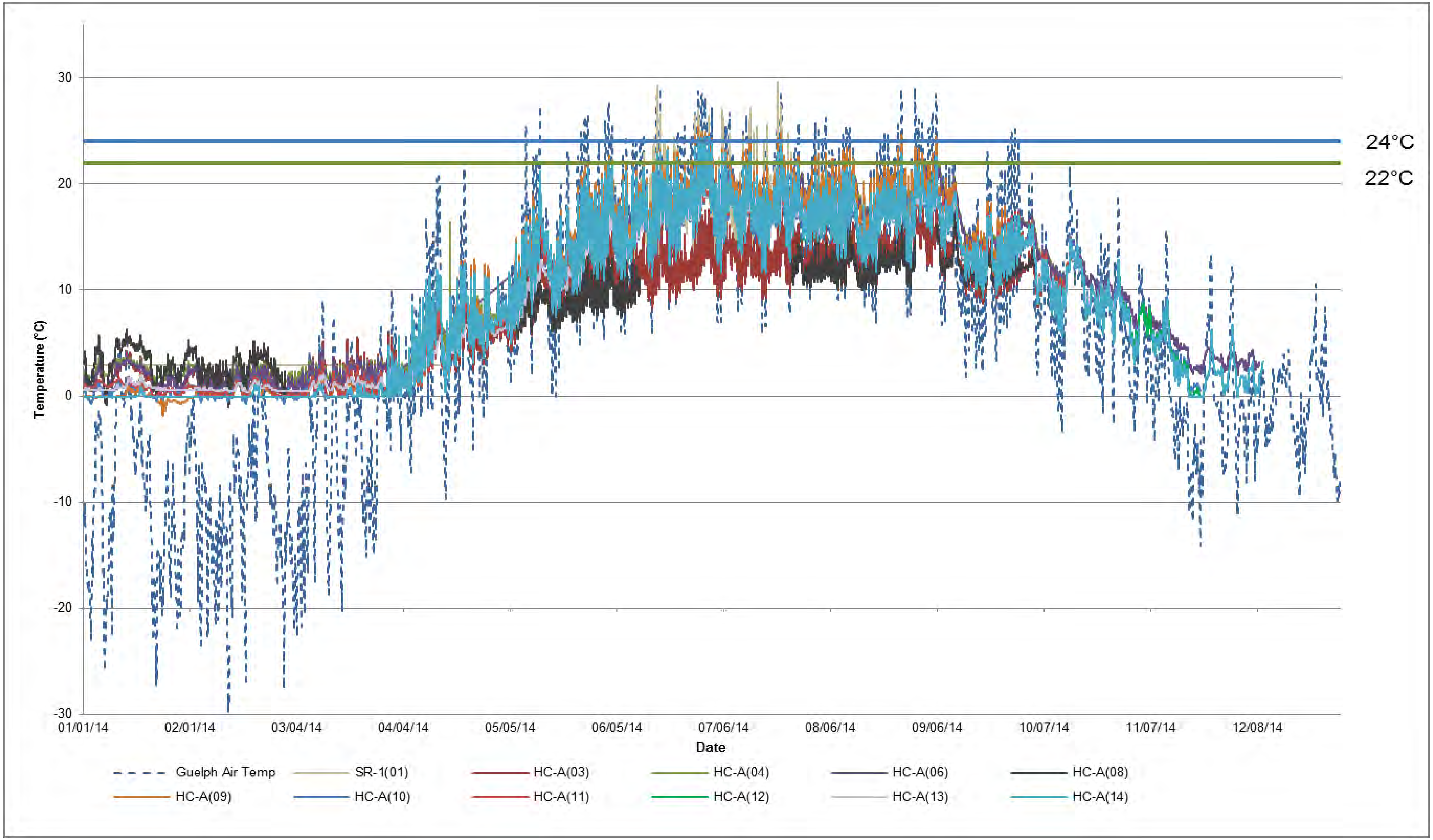


Figure 3. Tributary A and A1 Temperature Monitoring – Continuous Temperature for 11 Stations, January to December 2014

The surface water temperatures were somewhat lower in 2014 compared to 2012 and 2013, with the exception of the influence of Pond 4. Compared to other years of monitoring, results for 2014 were generally normal to somewhat cool. Stations HC-A(04) and HC-A(06) are the notable exceptions, as they continued to have higher temperatures due to the influence of the continuous discharge from SWM Pond 4.

The generally normal to cool water temperatures are attributable to the observed air temperatures in the summer of 2014. Daily average air temperatures from May to September 2014 were generally at or below climate normal with the exception of June. The overall average was equal to the climate normal for the months of May and September; above climate normal in June, and below climate normal in July and August. This resulted in the normal to cooler surface water temperatures in 2014.

Table 5 shows the thermal regime classifications for Tributaries A and A1 from 2006 to 2014 using the methods developed by Stoneman and Jones (1996) and revised by Chu (2009). The 2014 classifications show similar conditions to those in 2013 and other previous years. Comparing 2013 and 2014 results, station HC-A(04) shifted from cool-warm to cool, and station HC-A(13) shifted from cool to cool-warm. The other stations remained the same. The 2012 classifications reflect the drought conditions that year.

Table 5. Temperature Classification Summary

	Based on C. Chu et al. (2009)							Based on Stoneman and Jones (1996)	
Station	**2014**	**2013**	**2012**	**2011**	**2010**	**2009**	**2008**	**2007**	**2006**
HC-A(03)	Cool-Cold	Cool-Cold	Cool	Cool	n/a	n/a	n/a	n/a	n/a
HC-A(04)	Cool	Cool-Warm	Warm	Cool	Cool	Cool-Cold	Cool-Cold	Cold	Cold
HC-A(06)	Cool-Warm	Cool-Warm	Warm	Cool	Cool	Cool-Cold	Cool-Cold	Cool	Cool
HC-A(08)	Cold	Cold	Cool-Cold	Cold	Cold	Cold	Cold	Cold	Cold
HC-A(09)	Cool-Warm	Cool-Warm	Warm	Cool-Warm	Cool-Warm	n/a	Cool	Cold	Cool
HC-A(10)	Cool-Warm	Cool-Warm	Cool-Warm	Cool-Warm	Cool-Cold	n/a	Cool-Cold	Cool	Cool
HC-A(11)	Cool	Cool	Cool-Warm	Cool	Cool	Cool-Warm	Cool	Warm	Warm
HC-A(12)	Cool	Cool	Warm	Cool-Warm	n/a	n/a	n/a	n/a	n/a
HC-A(13)	Cool-Warm	Cool	Warm	Cool-Warm	n/a	n/a	n/a	n/a	n/a
HC-A(14)	Cool-Warm	Cool-Warm	Warm	Cool-Warm	Cool-Warm	Cool	Cool	n/a	n/a

Comparing 2014 results to pre-construction years (2006 to 2010), it is evident that there is some warming that is likely attributable to the effects of SWM Pond 4. Stations HC-A(04), HC-A(06), HC-A(09) and HC-A(10) were warmer in 2014. This may be attributable, at least in part, to the influence of SWM Pond 4. Further downstream, station HC-A(11) was cooler in 2014 compared to pre-construction condition. Station HC-A(11) was similar or cooler, which may reflect the cooling effect of the removal of the online pond in conjunction with building the Hanlon Creek Blvd crossing of Tributary A in 2009. Station HC-A(14) was one category warmer in 2014 compared to pre-construction conditions. Stations HC-A(12) and HC-A(13) did not exist prior to construction. Beginning in 2011, the results for those stations suggest that the only influence has been the warmer climate conditions in 2012. Altogether, the majority of the stations with warmer thermal regimes occur in the section of Tributary A that is most likely to be influenced by SWM Pond 4.

2.4.2.1 Suitability of Temperature for Brook Trout

While the thermal classifications are informative, they are only indirectly connected to suitable temperatures for fish species. The ability of a stream to support a cold water fish species can be determined based on the temperatures that occur in the summer (July and August) in comparison to the temperature requirements of the species. In general, water temperatures observed in 2014 were above the preferred temperatures documented for Brook Trout in the *Hanlon Creek Business Park Stream Temperature Impact Report Continuous Modeling with HSP-F* (AECOM, 2009). This is evidenced by several measures of temperature at the continuous monitoring stations.

Stream temperatures in 2014 exceeded the preferred summer temperature range for Brook Trout, which is from 10 to 19°C. Table 6 shows that all but two of the stations had periods of time when temperatures were above 19°C in July and August. Stations HC-A(04) and HC-A(06) were influence by the continuous outflow from SWM Pond 4, and spent half of the time in July and August above 19°C. In contrast, station HC-A(03) is located immediately upstream of the SWM Pond 4 outflow, and had no time when the stream temperature was above 19°C. Station HC-A(09) also had substantial time when the temperature was above 19°C. Station HC-A(08) is located on Tributary A1 which is typically colder, and this station had no time above 19°C. Downstream of the confluence of Tributary A and Tributary A1 at HC-A(10), the combined flow had some time above 19°C, but the results were clearly influenced by the colder water from Tributary A1. Station HC-A(11) had less time over 19°C in July and August, suggesting additional groundwater input. Moving downstream through stations HC-A(12), HC-A(13) and HC-A(14), the time above 19°C increased, reflecting the loss of water to the ground known to occur in this reach, and exposure to the sun that occurs early in the summer before the herbaceous vegetation is fully grown in this area. Overall, many parts of Tributary A had periods when temperatures were above the preferred summer temperature range for Brook Trout, with Tributary A1 and the upper end of Tributary A being the only locations that remained within the preferred range for all of July and August.

Table 6. Summer (July to August) 2014 Temperature Summary

Station	Modeled Values[1,2]	HC-A(03)	HC-A(04)	HC-A(06)	HC-A(08)	HC-A(09)	HC-A(10)	HC-A(11)	HC-A(12)	HC-A(13)	HC-A(14)	SR-1(01)
Summer (July-August) average maximum (ºC)	14.5 - 19.9	15.68	20.03	20.42	8.55	21.80	19.63	18.63	19.18	20.12	20.41	22.87
Summer (July-August) average (ºC)	12.5 - 14.5	13.13	19.02	18.95	12.21	18.62	16.88	16.97	17.11	17.29	17.35	17.12
Summer (July-August) average minimum (ºC)	9.0 - 12.0	11.23	18.06	17.79	6.17	16.36	14.82	15.60	15.41	14.92	14.78	13.21
Maximum 3-day mean (ºC)	14.0 - 19.0	14.72	20.27	20.10	13.38	20.43	18.74	18.89	19.36	19.52	19.55	19.29
Maximum 7-day mean (ºC)	13.0 - 17.0	14.28	19.61	19.51	12.95	19.47	17.76	17.87	18.38	18.37	18.46	18.49
Maximum 7-day mean of daily maximums (ºC)	15.0 - 23.5	16.88	21.05	21.58	15.53	23.03	21.20	19.88	21.12	21.76	22.43	24.89
	Temperature Exceedance over 19°C for July and August											
Hours over 19°C	0 - 130	0	771	729	0	622	222	136	218	350	383	381
Percent of Time over 19°C	0 - 9%	0%	52%	49%	0%	42%	15%	9%	15%	24%	26%	26%
Frequency of Exceedance over 19°C (Days)	0 - 27	0	53	56	0	60	40	23	28	46	50	58
Average Duration of Event Over 19°C (h)	3 - 6	0	16.76	12.35	0	10.90	5.28	5.89	7.52	7.61	7.37	5.44
Maximum duration of event over 19°C (h)	<<130	0.00	98.75	59.50	0.00	37.25	16.00	17.75	27.25	26.25	25.00	16.00
	Temperature Exceedance over 22°C for July and August											
Hours over 22°C		0	4	5	0	106	10	0	11	28	41	121
Percent of Time over 22°C		0%	0%	0%	0%	7%	1%	0%	1%	2%	3%	8%
Frequency of Exceedance over 22°C (Days)		0	2	2	0	26	4	0	3	6	9	38
Average Duration of Event Over 22°C (h)		0	0.95	1.01	0	2.66	1.97	0	2.06	2.87	4.50	2.09
Maximum duration of event over 22°C (h)	<<130	0.00	2.25	2.50	0.00	9.75	5.25	0.00	4.75	8.75	9.50	7.75
	Temperature Exceedance over 24°C for July and August											
Hours over 24°C	0 -3.2	0	0	0	0	14	0	0	0	0	3	44
Percent of Time over 24°C	0 - 0.21%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	3%
Frequency of 24°C Exceedance (Days)		0	0	0	0	6	0	0	0	0	1	19
Average Duration of Event Over 24°C (h)		0	0	0	0	2.25	0	0	0	0	1.50	1.81
Maximum duration of event over 24°C (h)	<3.2	0.00	0.00	0.00	0.00	4.50	0.00	0.00	0.00	0.00	2.00	4.75

[1] Modeled range referees to the results of the Hanlon Creek Business Park Stream Temperate Impact Report Continuous Modeling with HSP-F (AECOM, 2009)

[2] Red text denotes exceedances of the modeled range

Maximum temperatures were also reviewed and provide further evidence that the temperatures in 2014 were not suitable for Brook Trout. The HCBP Consolidated Monitoring Plan established two thresholds for Brook Trout; the first is a single temperature exceedance of 22.0°C, and the second is any single temperature exceedance of 24.0°C. The highest number of exceedances of these thresholds since monitoring began occurred in the year 2012. Comparatively fewer exceedance events occurred in 2014, yet exceedences of both thresholds were still observed (Table 6).

Temperatures in excess of 22°C are not suitable for Brook Trout. Station HC-A(09) exceeded 22°C for 106 hours in July and August, which is 7% of this time period, and station HC-A(14) exceeded 22°C for 41 hours or 3% of the time period (Table 6). It has been typical for station HC-A(14) to exceed both thresholds because of loss of water and exposure to the sun in this part of Tributary A. Other stations on Tributary A had lesser periods of time above 22°C in July and August. While the resulting time periods for those stations are a modest proportion of July and August, temperatures above 22°C are not suitable for Brook Trout, and adverse effects can occur even if the temperatures are not lethal. Only stations HC-A(03), HC-A(08) and HC-A(11) had temperatures that remained below 22°C.

Temperatures above 24°C can be lethal for Brook Trout, and two stations had temperatures above 24°C during July and August 2014. Station HC-A(09) exceeded 24°C on six occasions, for an average of 2.25 hours totaling 14 hours (Table 6). Station HC-A(14) exceeded 24°C on one occasion for 3 hours. The RAAP team normally meets whenever temperatures exceeded 24°C at telemetry stations to discern the cause and try to address it. In 2014, the exceedances went unnoticed. Most of them were at station HC-A(09), which is not a telemetry station. The exceedence at HC-A(14) was not registered by the telemetry temperature logger, which was found later in the year to be malfunctioning. A standard logger was also maintained at HC-A(14) for redundancy, and its data set includes temperature measurements above 24°C.

2.4.2.2 Stormwater Management Pond Temperature

In addition to the monitoring of stream temperatures, monitoring was conducted at the constructed stormwater management facilities, which included SWM Pond 1, SWM Pond 2, and SWM Pond 4 (Map 4). Temperature was measured at each pond’s inlet, at three depths near the bottom-draw outlet, at the outlet of the pond, and at the outlet of the cooling trench (where applicable).

SWM Pond 1

Flow was regularly entering SWM Pond 1 via the grassed swale in 2014, even during some dry periods as well as during storm events. The logger at the outlet was stolen multiple times and data for this location is not available. However, data is available for the cooling trench outlets. The thermal stratification was evident within the pond, demonstrated by the bottom and mid temperatures converging during the mixing caused by a storm event, and then diverging again the following day (Figure 4). The surface temperature (not shown in Figure 4) had the greatest diurnal temperature fluctuation during the summer. The cooling trenches (labeled 1 and 2 on Figure 4) demonstrated steady to declining temperatures through the storm event. Cooling trench 1 generally maintained lower temperatures than Cooling Trench 2.

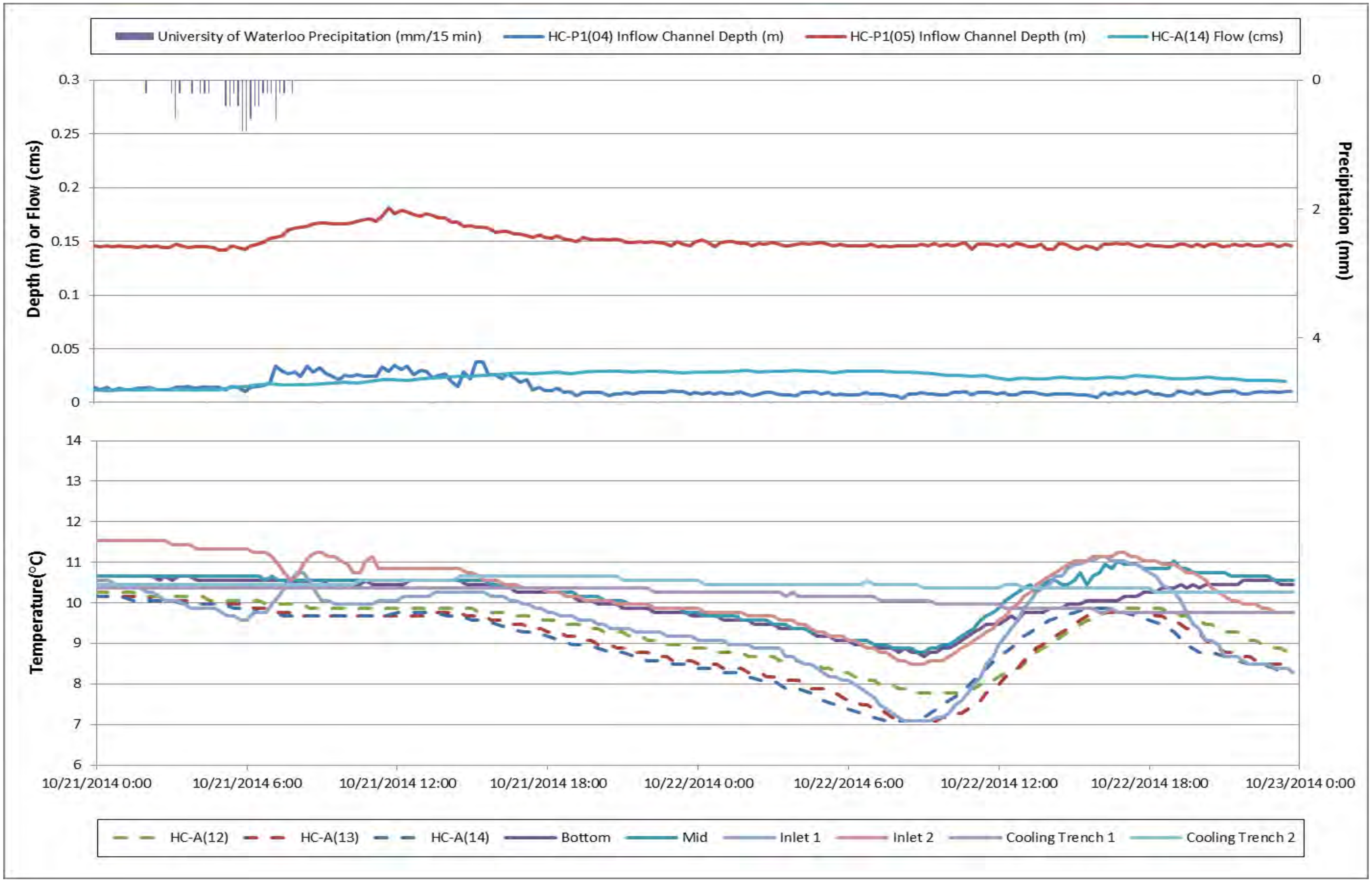


Figure 4. SWM Pond 1: Computed outflow, measured inflow channel depth, and measured temperatures within and exiting the pond; precipitation; measured temperatures on Tributary A upstream (HC-A(12)) and downstream (HC-A(13, 14)) of Pond 1.

SWM Pond 2

The thermal stratification was evident with the bottom temperature generally remaining more stable than the surface temperature. This is evident for the period of September 16 to 19 on Figure 5. SWM Pond 2 discharges to an infiltration gallery, so outlet temperatures are not monitored.

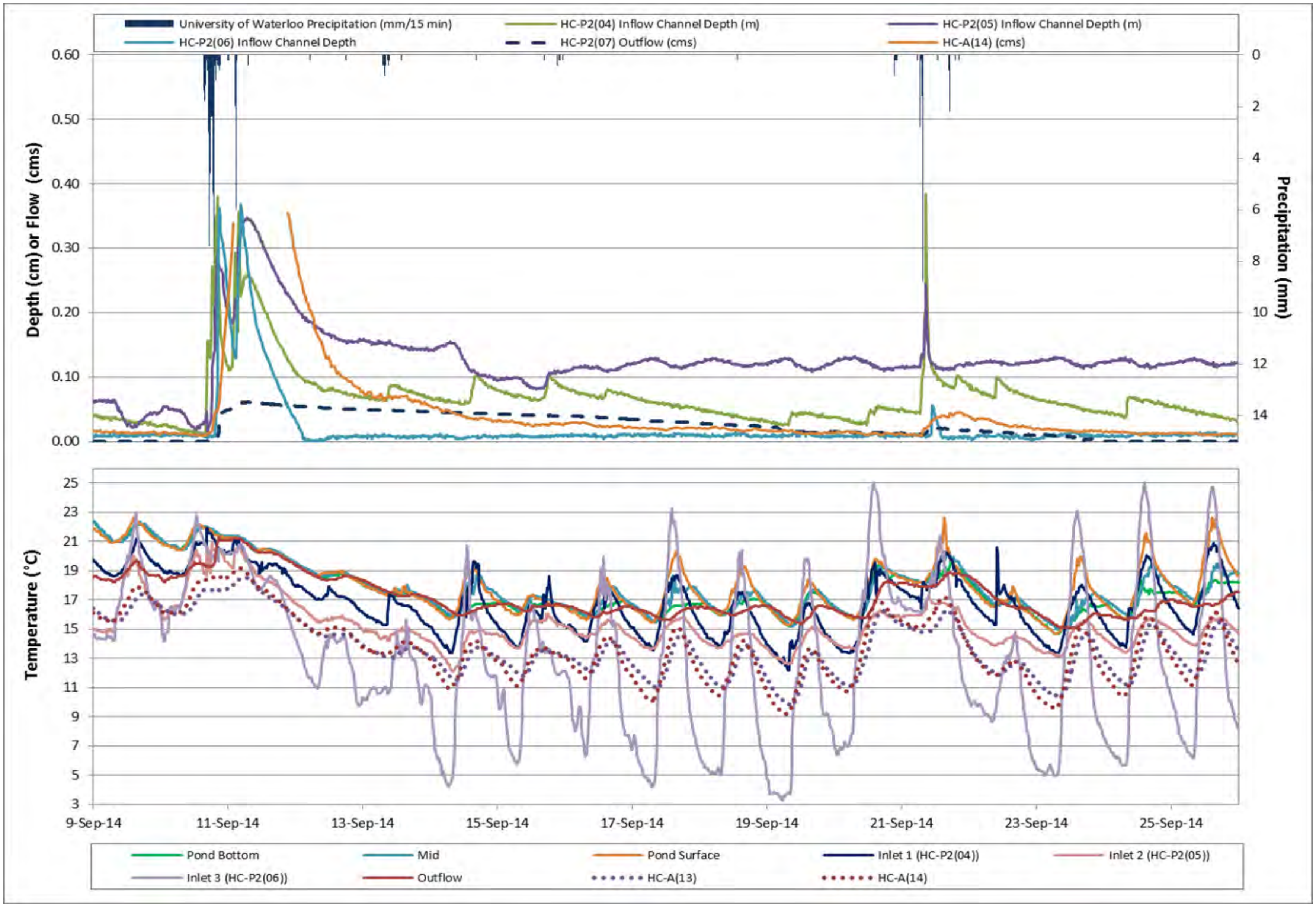


Figure 5. Computed outflow, measured inflow channel depth, and measured temperatures within and exiting pond; precipitation; measured temperatures on Tributary A (HC-A(13)) upstream and downstream (HC-A(14)) of pond 2.

SWM Pond 4

As discussed in Section 2.3, SWM Pond 4 continued to discharge continuously, augmenting flow in Tributary A. It also experienced numerous storm events that discharged to Tributary A.

The pond temperatures continued to be strongly stratified during the summer, with bottom temperatures that were much more stable than surface temperatures. Figures 6 and 7 demonstrate how the cooling trench maintained lower temperatures than the pond, yet were higher than upstream water temperatures in Tributary A at station HC-A(03). The resulting water temperatures downstream in Tributary A at station HC-A(04) are strongly influenced by the pond's discharge through the cooling trench. This demonstrates that the cooling trench is generally functioning as intended, although the continuous discharge is increasing stream temperatures in Tributary A.

It appears that during dry periods the cooling trench was receiving water as outflows from the pond (outflow) combined with direct reception of groundwater. This explains why, during a dry period, the cooling trench water temperatures were midway between the pond outflow temperature and the upstream Tributary A temperatures at station HC-A(03) (Figure 7). The upstream temperatures in Tributary A appear to have been strongly influenced by groundwater with moderate diurnal fluctuation. The temperatures were consistent with groundwater temperatures at up-gradient monitoring wells MW 131 and MW 122A, which reached approximately 12 to 13°C in the summer of 2014. The diurnal fluctuation in stream temperatures is interpreted to represent solar radiation and warm air temperatures that increased stream temperatures above groundwater temperatures during daylight hours. The pond outflow temperatures were considerably higher than the stream and groundwater temperatures. The fact that the cooling trench temperatures were in between suggests that they were a result of a mixture of pond outflow water and groundwater.

Cooling trench performance during a storm event further demonstrates how the mixing of SWM Pond 4 outflow (the water entering the cooling trench from the pond) and groundwater occurs. In response to a storm, the cooling trench temperatures were closer to pond outflow temperatures (Figure 6). This can be attributed to the greater volume of pond outflow, which has the greater influence on cooling trench temperature.

Following the storm event, the cooling trench temperature gradually returned to a more balanced blend of groundwater and pond outflow, trending in a manner consistent with the pond outflow volumes.

With the possible exception of a few hours after a storm, it appears that the cooling trench performed largely as a mixing chamber, with the rock doing only a little to absorb heat from the outflow water. The above discussion demonstrates that the outflow temperature influences that of the cooling trench, rather than the other way around. The cooling trench temperature responded very quickly to the inundation of outflow (Figure 6). Some heat was likely absorbed at the beginning of a storm, although this effect was limited and it dissipated beyond about 6 hours following the storm.

In September 2012, aquatic vegetation was planted in the pond and the outlet weir was raised to reduce the constant discharge from SWM Pond 4. Raising the weir height did not stop SWM Pond 4 from continuously discharging in 2013 or 2014. Plantings of vines and other flora was completed at the end of 2012on the cooling trench in an attempt to shade the exposed rock. The plants did not mature sufficiently in 2013 to cover the cooling trench, and this continued to be the case in 2014. These design features may provide additional cooling to the ponds discharge in future summer seasons. However, it may be necessary to implement other measures to further mitigate the effects on stream temperatures. Options for other mitigation measures will be determined through discussions with the City and the GRCA.

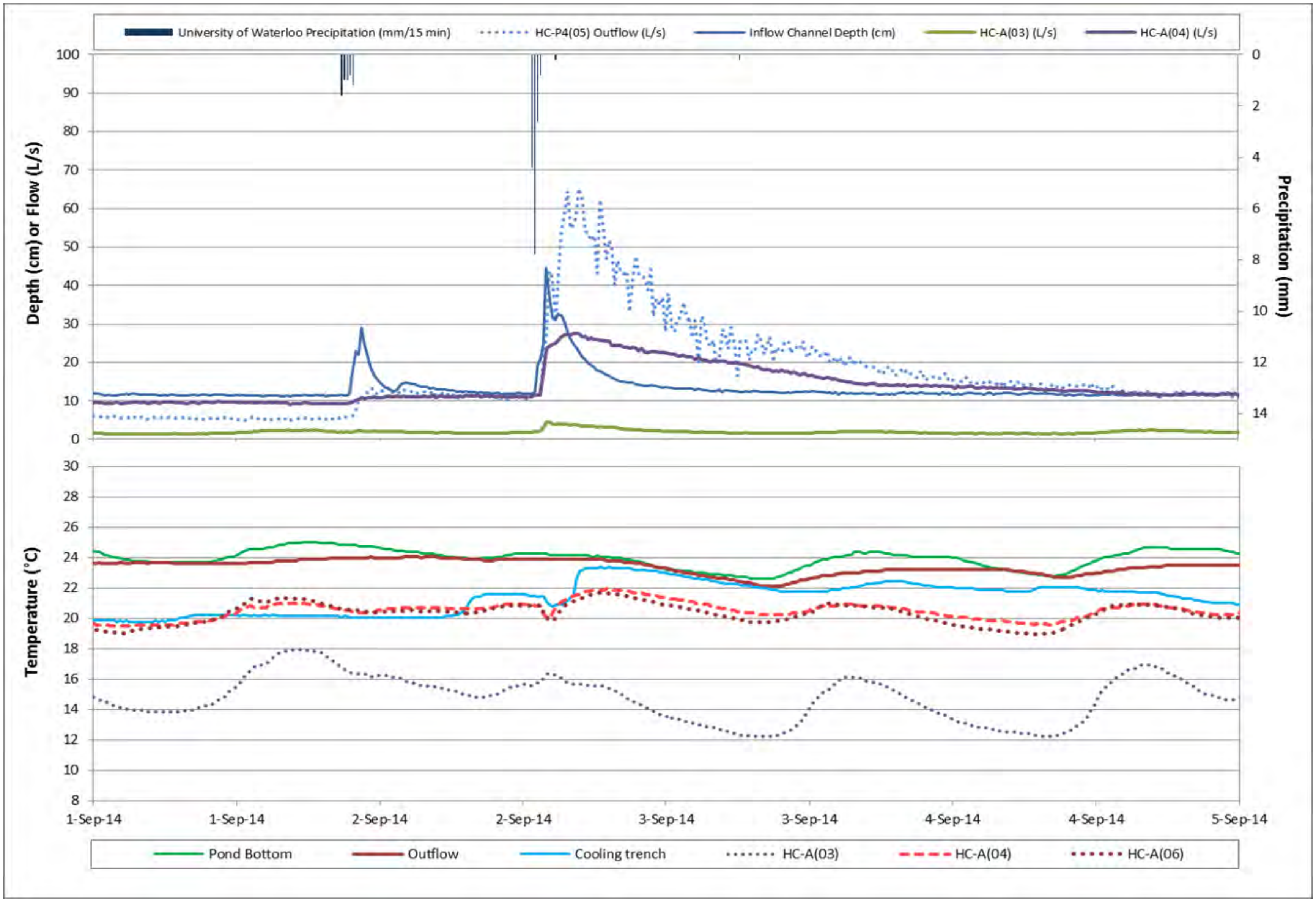


Figure 6. SWM Pond 4: Computed outflow, measured inflow channel depth, and measured temperatures within and exiting pond; precipitation; measured temperatures on Tributary A (HC-A(03)) upstream and downstream (HC-A(04, 06)) of Pond 4 during a wet period.

Figure 7. Pond 4: Computed outflow, measured inflow channel depth, and measured temperatures within and exiting pond; precipitation; measured temperatures on Tributary A (HC-A(03)) upstream and downstream (HC-A(04, 06)) of pond 4 during a dry period.

2.5 Water Quality

2.5.1 Groundwater Quality

The groundwater quality results are given in the 2014 technical memorandum prepared by Banks Groundwater Engineering (Appendix II) and discussed as follows.

Water samples were taken from 36 monitoring wells in April 2014. Each sampling period the wells are purged prior to sampling the equivalent of three casing volumes. The samples are also field-filtered with a 45 micron in-line filter. The groundwater at the HCBP can be characterized as basic (pH>7) and, based on the reported calcium and magnesium concentrations, as hard. Since 2003, the concentrations of the parameters analyzed have generally been below the applicable Ontario Drinking Water Quality Standards (ODWQS) criteria, with the following exceptions during the monitoring period (refer to Appendix II for specific exceedances):

- Nitrate (as N) concentrations exceeded the ODWQS of 10.0 mg/L on at least one occasion in six monitoring wells
- Aluminum concentrations exceeded the ODWQS of 0.1 mg/L on at least one occasion in 24 monitoring wells
- Cadmium concentrations exceeded the ODWQS of 0.005 mg/L on at least one occasion in 11 monitoring wells
- Iron concentrations exceeded the ODWQS of 0.3 mg/L on at least one occasion in 32 monitoring wells
- Lead concentrations exceeded the ODWQS of 0.010 mg/L on at least one occasion in 22 monitoring wells
- Manganese concentrations exceeded the ODWQS of 0.05 mg/L on at least one occasion in 37 monitoring wells
- Sodium concentrations exceeded the ODWQS of 20 mg/L on at least one occasion in 37 monitoring wells
- Hardness concentrations exceeded the ODWQS of 100 mg/L in all monitoring wells.

Colour, turbidity, total dissolved solids, and DOC exceeded the respective ODWQS concentrations in most of the monitoring wells. This observation is typical for monitoring wells that cannot be developed to a sediment-free condition. Therefore, it cannot be concluded that these four parameters are naturally above the respective ODWQS. Improved filtering of samples at the time of collection since 2009 has resulted in reduced levels of some parameters.

2.5.2 Surface Water Quality

2.5.2.1 In-Stream Water Quality

During each field visit an YSI multi-parameter probe (556R) was used to collect dissolved oxygen, pH, and specific conductivity conditions at each site. These results are shown graphically in Figures 8, 9 and 10, respectively. The majority of the sites were within the ranges of the Provincial Water Quality Objectives (PWQO). In the event that water quality samples were collected and the pH probe was not functioning, then the pH was determined by lab analysis.

During one of the baseflow monitoring events, dissolved oxygen (DO) was below PWQO guidelines (Figure 8). This occurred once (Oct. 9th) during the monitoring season at station HC-A (12). Lower DO levels observed on this date could be attributed to below average flow rates due to high temperatures and an extended period of no precipitation.

The number of days where pH levels were above PWQO guidelines was also recorded. This occurred one time each at HC-A (04) and HC-A (14). Both events were more acidic than PWQO guidelines (Figure 9).

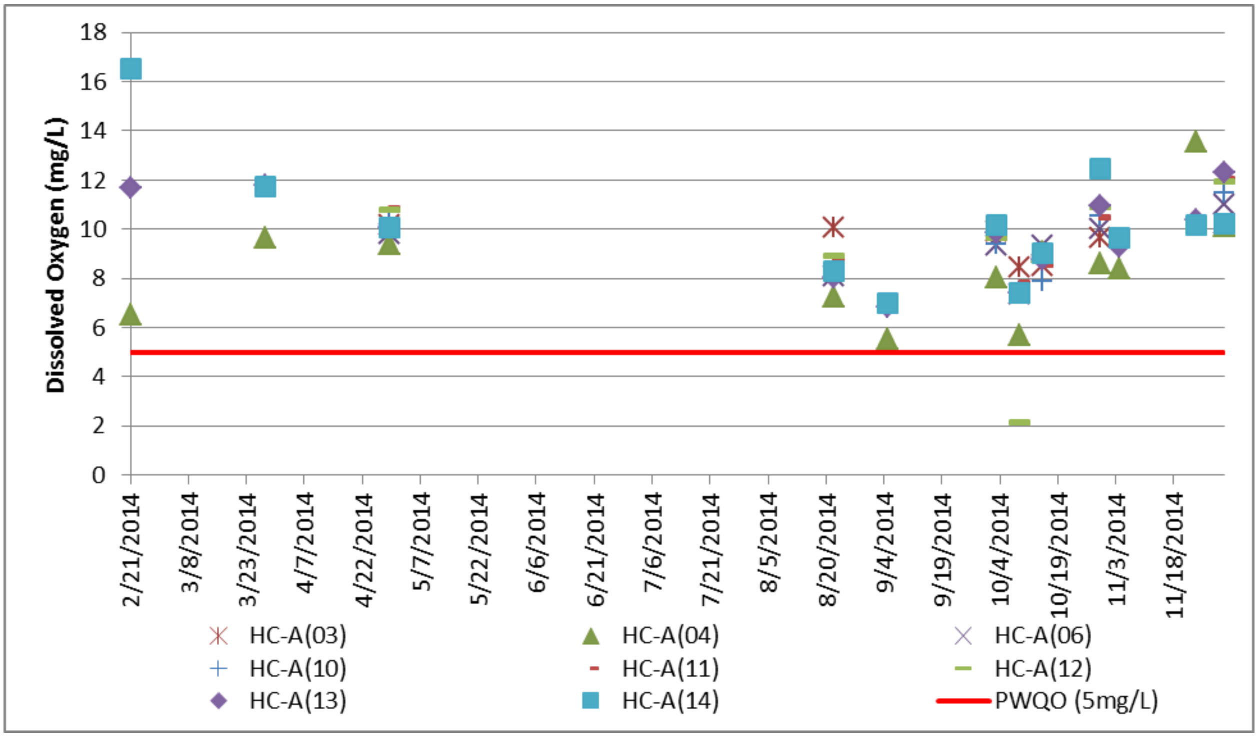


Figure 8. YSI Dissolved Oxygen Readings from 8 Monitoring Stations on Tributary A

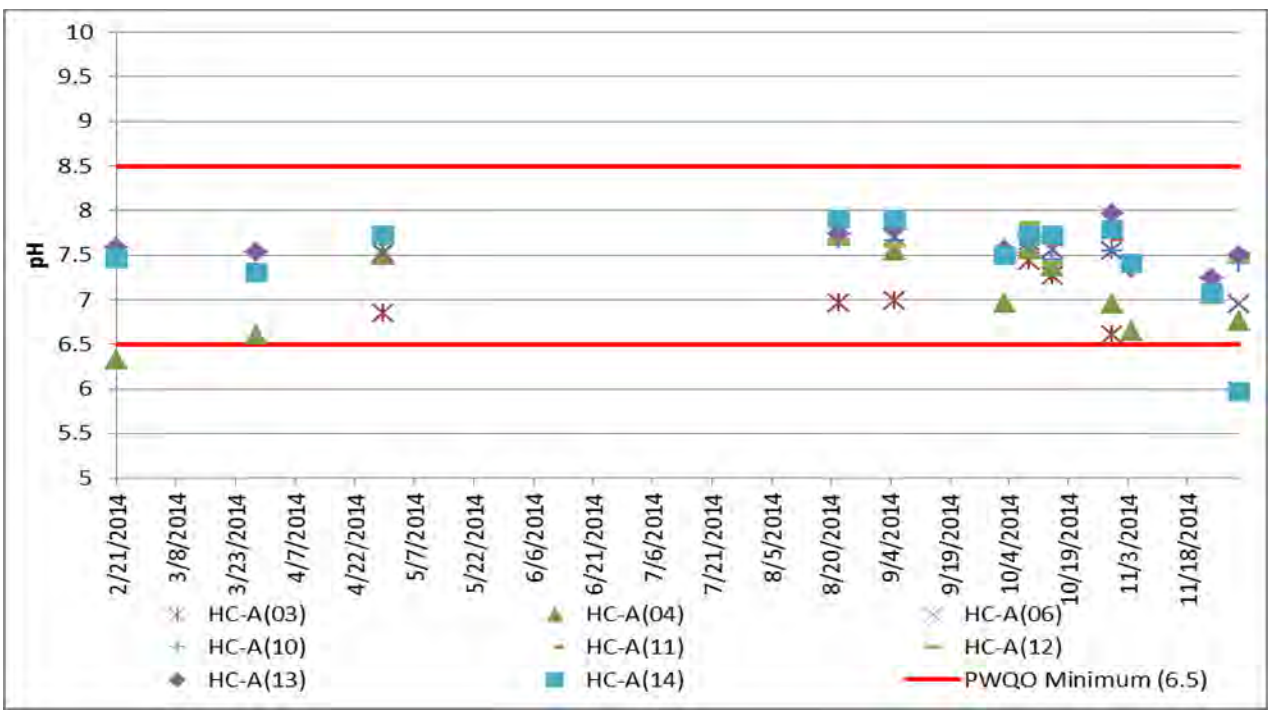


Figure 9. YSI pH Readings from 8 Monitoring Stations on Tributary A

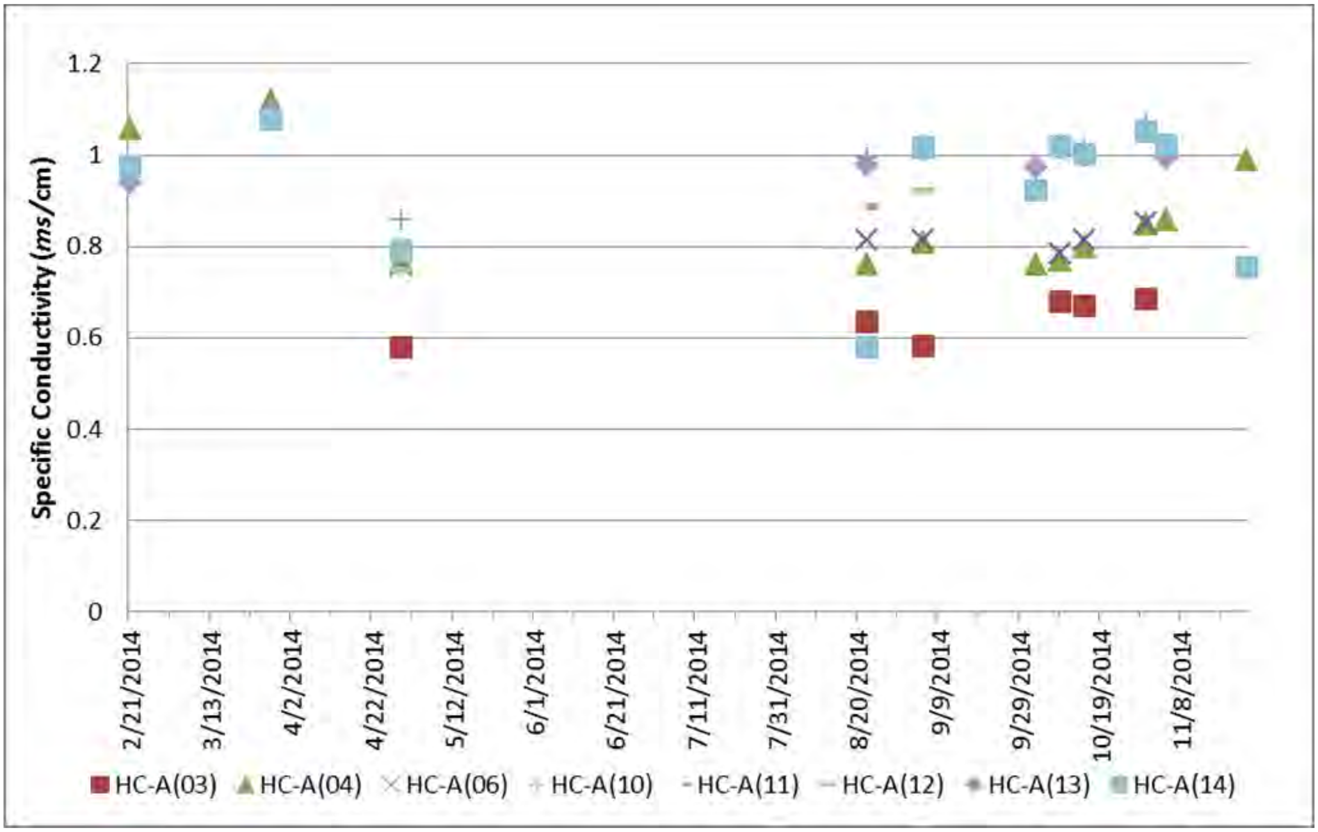


Figure 10. YSI Specific Conductivity Readings from 8 Monitoring Stations on Tributary A

In 2014, three turbidity monitoring stations were once again maintained along Hanlon Creek at stations HC-A(03), HC-A(06), HC-A(11) and HC-A(14) (Map 4). A Turner Designs Cyclops turbidity sensor uses an optical scattered light method to determine turbidity. Data was collected over the 2014 year; however some issues were encountered with the turbidity data. It appears that loggers at HC-A(11) and HC-A(14) were buried under sediment for extended periods of time causing the sensor to record maximum turbidity levels. It is recommended that the depths be adjusted in 2015 to avoid sediment overcoming the sensors. There is also potential that biofouling and vegetation growth in the stream interfered with the sensor readings during 2014. Figure 11 presents the turbidity monitoring results observed for the 2014 year.

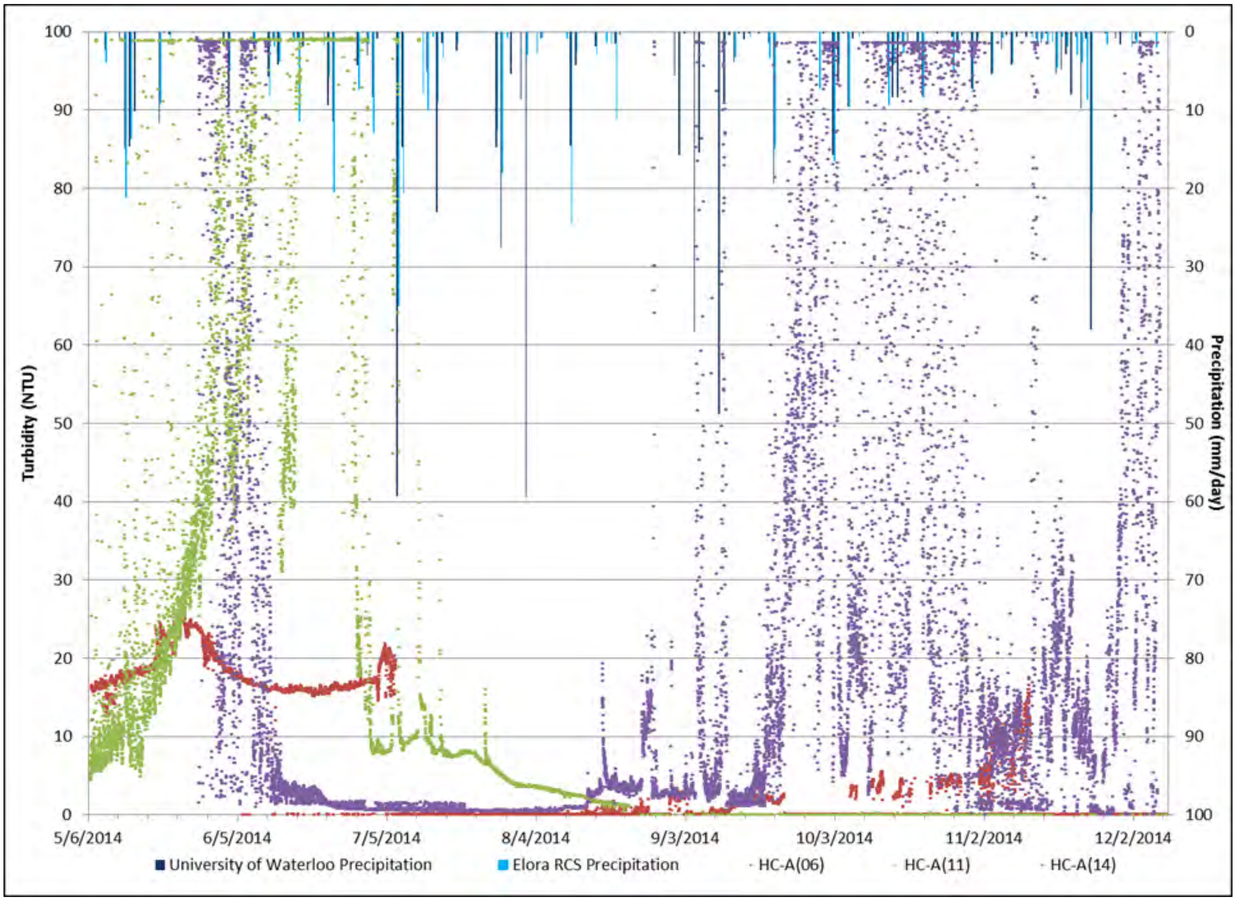


Figure 11. In-stream Turbidity Measurements for 2014

2.5.2.2 Stormwater Management Pond Water Quality

To establish the performance efficiency of the SWM facilities and to satisfy the MOE Certificate of Approval, the water quality sampling program consists of grab samples at the inlet, outlet and downstream of each pond. Parameters that were analyzed in 2014 included:

- CBOD (5)
- Total Suspended Solids
- Total Phosphorus
- Dissolved Phosphorus
- Metals (total and dissolved, lead, zinc and copper)
- Escherichia coli
- Nitrate as N
- Chloride

The Consolidated Monitoring Program included the following water quality sampling requirements:

- One sample per season (Winter and Fall) within one hour commencement of a storm event;
- Five wet weather samples collected during summer months (June-September);
- One sample collected during the snowmelt freshets (Spring);
- Three dry samples taken 72 hours after a wet weather event

Eight wet weather samples were collected over the course of the 2014 monitoring season. Both the winter and spring freshet samples were collected. Four wet weather samples were collected between April and October 2014. The remaining two wet weather samples were taken during the month of November. Only two of the three dry weather samples were collected and both samples were taken during the summer of 2014. From May to October, water levels at Pond 1 and 2 were too low prior to a rainfall event to result in stormwater being discharged from the outlet into Hanlon Creek Tributary A. Therefore, samples collected at Pond 1 and 2 were not taken during discharge events. As a result, the only interactions between these SWM facilities and Hanlon Creek Tributary A would have occurred through groundwater interactions. Samples collected during non-discharge periods in the summer months were taken directly from the SWM facilities. As such, the water samples did not necessarily represent the water flowing into Hanlon Creek Tributary A. Pond 4 was discharging during the summer months and stormwater samples were collected from the pond outlet. The tabular results of the water quality sampling have been included in Appendix E of the surface water report (Appendix III of this report).

Water quality sampling results are presented as a number of exceedances as compared to the PWQO in Table K **Error! Reference source not found.**of the surface water r eport (Appendix III). A number of water quality parameters were typically higher in the SWM facilities with lower concentration in Hanlon Creek. *E.Coli* concentrations exceeded the recommended PWQO guidelines for recreational use for both wet weather and dry weather sampling events. Total phosphorus showed an overall reduction in phosphorus levels as the water moved though the pond. The in-stream phosphorus levels exceeded the PWQO during both wet and dry weather sampling events. However; this is not uncommon for streams in the Grand River watershed (GRCA 2012). Nitrate, total suspended solids, copper and lead all showed higher concentrations entering the SWM facilities with concentrations decreasing in the outlet samples. Aluminum, cadmium, copper, iron, lead, vanadium and zinc exceeded PWQO in the SWM facilities. However, instream levels did not exceed PWQO guidelines for aluminum or vanadium. Copper, iron, lead and zinc exceeded PWQO guidelines for both wet weather and dry weather sampling events. Zinc concentration in both the SWM facilities and instream exceeded PWQO.

In 2011, the Canadian Council of Ministers of the Environment (CCME) set standards for chloride exposure indicating increased risk of harm to aquatic life after long term exposure to concentrations above 120 mg/L and short term exposure to concentrations above 640 mg/L (CCME 2011). Chloride concentrations were typically higher at pond outlets and in-stream locations, compared to samples taken at pond inlets. However, inlet chloride levels sharply increased during winter sampling. Short term exposure targets were exceeded at pond inlets HC-P1(04,05), HC-P2 (04,05) and HC-P4(05) during winter sampling events.

2.6 Aquatic Habitat and Biota

Aquatic monitoring was conducted for the benthic invertebrate and fish community within Tributary A and Tributary A1 of Hanlon Creek. Monitoring in 2014 was conducted at five different sites, each with a benthic invertebrate sampling station and a quantitative fish sampling station. Aquatic habitat information was collected at each station. Brook Trout spawning surveys were conducted on three separate occasions in fall 2014 along sections of Tributary A and Tributary A1. Locations of the ten sampling stations are shown on Map 5, along with the Brook Trout spawning search area.

To assess the benthic invertebrate community, several indices were calculated to provide a characterization of the community at each station and to allow for comparisons across years. The indices calculated for 2014 include the Percent Model Affinity (PMA) index, which generates Percent Similar Community (PSC) values. Values that are higher than the critical PSC value indicate no impact, while values that are lower than the critical PSC value indicate impact at that station. Other indices were taxonomic richness, Ephemeroptera, Plecoptera and Trichoptera (EPT) richness, and percent dominant taxon.

To assess the fish community, multi-pass electrofishing surveys were conducted. This involved isolating a section of stream using nets and electrofishing that section multiple times until there was a decline in the number of fish captured in subsequent passes with the electrofisher. Following the identification and enumeration of the catches, population estimates were calculated for four of the monitoring stations using a maximum likelihood constant P method (Schnute 1983). A least squares regression statistical method (Zippen 1958) was used for station EMS-005 because the resulting data was not suited to the former method.

Detailed results from the aquatic monitoring program are provided in the 2014 aquatic monitoring report prepared by NRSI (Appendix IV) and are summarized and discussed in Sections 2.6.1 and Section 2.6.2 below.

2.6.1 Benthic Community

The benthic invertebrate index results are shown on Figures 12 (taxa richness), 13 (EPT Taxa Richness) and 14 (Proportion of dominant taxon), and in Table 7 (PMA analysis).

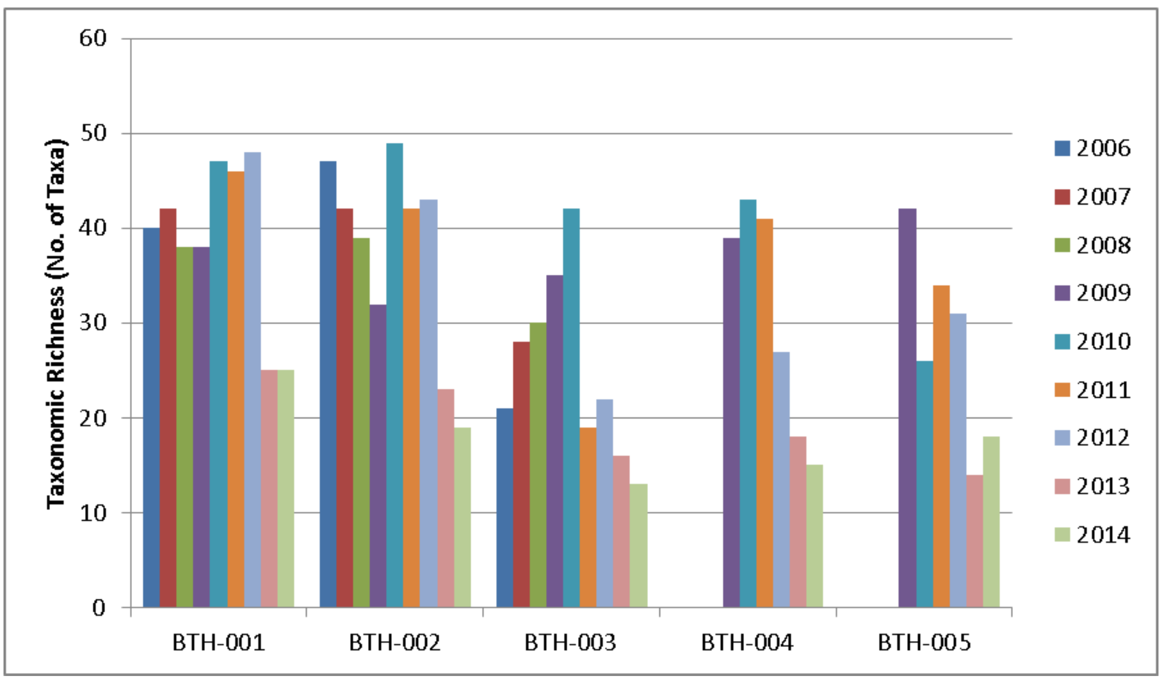


Figure 12. Benthic Invertebrate Taxonomic Richness for the Years 2006 to 2014

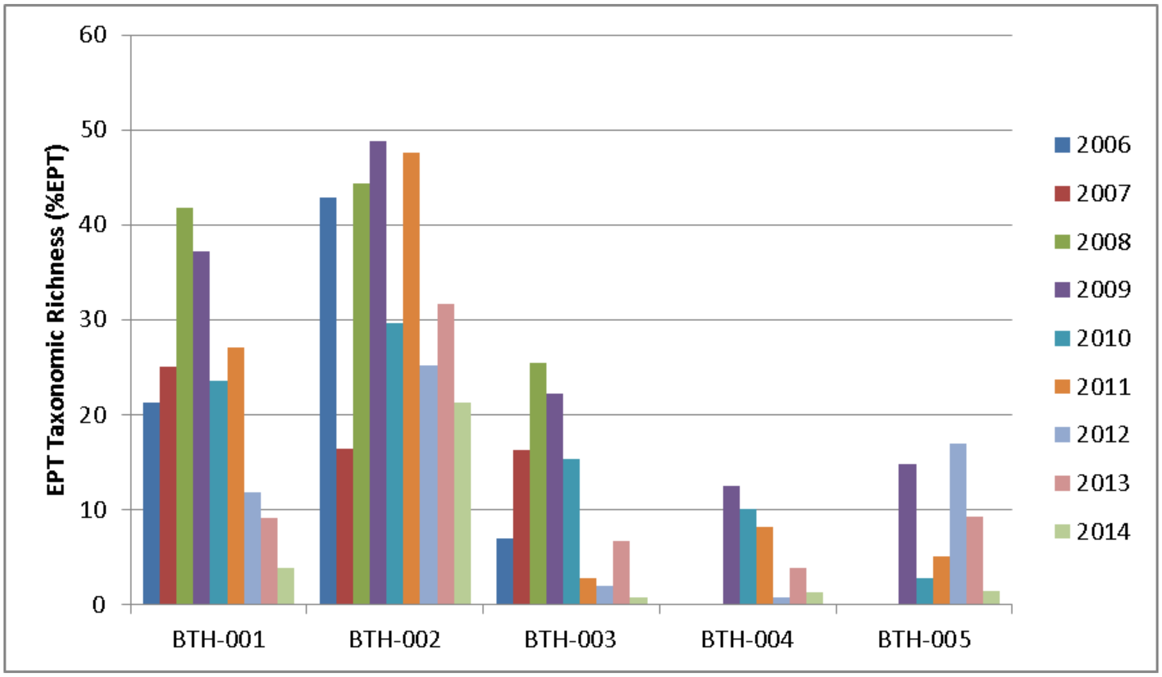


Figure 13. Benthic Invertebrate EPT Taxa Richness for the Years 2006 to 2014

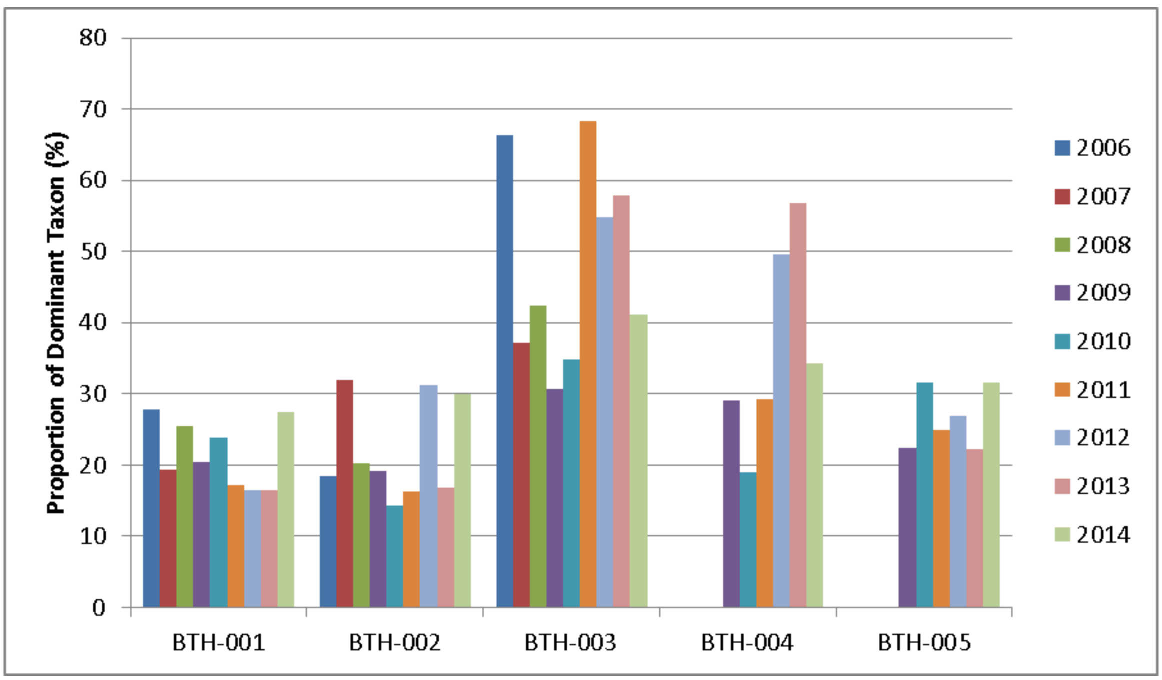


Figure 14. Benthic Invertebrate Proportion of Dominant Taxa for the Years 2006 to 2014

Table 7. Percent Similar Community Values and Impact Determination

Station	Result	2006	2007	2008	2009	2010	2011	2012	2013	Critical PSC	2014 Sample PSC	2014
BTH – 001	Impact									42.12	68.08	
	No Impact	X	X	X	X	X	X	X	X			X
BTH – 002	Impact	X		X	X		X	X	X	50.7	45.56	X
	No Impact		X			X						
BTH – 003	Impact							X	X	42.12	45.81	
	No Impact	X	X	X	X	X	X					X
BTH – 004	Impact	-	-	-				X	X	42.12	32.30	X
	No Impact	-	-	-	X	X	X					
BTH – 005	Impact	-	-	-						42.12	35.37	X
	No Impact	-	-	-	X	X	X	X	X			

Station BTH-001

Taxonomic richness has remained similar at station BTH-001 throughout the 5 years of pre-construction monitoring and into the early stages of construction-phase monitoring. The number of taxa has varied from 25 to 48 with the highest level of richness recorded in 2012 (Figure 12). In 2013 a decline was noted with numbers dropping from 48 to 25, the lowest that had been observed to date. Taxonomic richness in 2014 remained low with a richness of 25. In 2013 it was determined that this low taxa richness was largely a function of the level of identification of the benthic invertebrates, which changed between 2012 and 2013 with a change in taxonomic methods. This continued into 2014, resulting in a similarly low richness. With this factored into the results, no consistent trends have been established at BTH-001 as it relates to taxonomic richness.

The EPT richness values declined at BTH-001 from 9.1 in 2013 to 3.9 in 2014. The 2014 value was the lowest to date at this station, and continued a decline that began with a substantial decrease between 2011 and 2012. EPT richness values were slightly higher in 2006, 2007, 2010, and 2011, with minor variations between years (Figure 13). The results from 2008 and 2009 baseline monitoring years stand out as being uncharacteristically high for this station. The decline in EPT richness that has been observed between 2011 and 2014 resulted in a threshold exceedance for the third consecutive year at BTH-001. This threshold exceedance is discussed in Section 5.2.2.

The dominant taxon in 2014 belonged to *Chironominae*, a subfamily of Chironomidae. This includes a species of non-biting midge (Diptera). Species belonging to this family primarily inhabit freshwater lotic environments throughout erosional and depositional areas. They are generally burrowers and belong to the functional feeding group 'collectors', including both gatherers and scrapers (Merritt et al. 2008). The conditions at station BTH-001 are consistent with this generalized habitat description providing silt, sand and gravel substrates, as well as moderately abundant detritus and woody debris. *Chironominae sp.* exhibit a range of tolerances as it relates to water quality, although in general they are indicative of fair to fairly poor water quality (Mandaville 2002). This species represented 27.5% of the total number of individuals in the sample (Figure 14) and dominated the sample for the first time in 2014. The second and third most abundant species within the sample were also subfamilies belonging to the Chironomidae family. These were *Orthocladiinae and Tanypodinae*, which comprised 18.3% and 11.4% of the sample, respectively. The remainder of the sample was largely comprised of three different species, including *Gammarus pseudolimnaeus* (10.2%), *Optioservus fastiditus* (8.4%), and *Caecidotea intermedius* (3.4%), most of which have provided a large representation within the samples through the previous years of monitoring. This site has had five other dominant taxa in the previous eight years of monitoring.

The PMA index continued to show 'no impact' in 2014. This has been a consistent result throughout all years of pre-construction monitoring, beginning in 2006, and continuing during construction-phase monitoring (Table 7). Prior to 2014 the overall results suggest that habitat and water quality conditions at station BTH-001 have generally remained consistent, aside from some expected natural variation. The decrease in EPT species at this site in 2012, 2013 and again in 2014 indicates a potential change in conditions. Based on the PMA assessment, this change was not enough to characterize the site as being 'impacted'. It is possible that the changes in flow due to the continuous discharge of SWM Pond 4, is causing the benthic community to change. This pattern will be further assessed during construction-phase monitoring in 2015.

Station BTH-002

Taxonomic richness at station BTH-002 was 19 in 2014. Results show a second consecutive year where the taxonomic richness has declined to the lowest levels to date.

This metric experienced a steep decline in the taxonomic richness between 2012 and 2013 from 43 to 23. Previously, the lowest observed richness at BTH-002 was 32 in 2009, which increased to a high of 49 in 2010 (Figure 12). The result in 2013 is likely a function of the level of identification of the benthic invertebrates, which changed from 2012 to 2013 and continued in 2014. No consistent trends have been established at BTH-001 as it relates to taxonomic richness. The decrease in taxonomic richness did not exhibit a greater than 50% decline in 2013, and therefore did not exceed the benthic threshold in 2014; however these low levels will be taken into account during the 2015 season.

The EPT richness was 21.3% in 2014, a decrease from 31.6%, which was observed in 2013. This metric has shown no obvious increasing or declining trend since 2006. EPT richness has frequently been high (above 40%) with large declines noted in 2007 (16.4%), 2010 (29.6%), and most recently in 2012 (Figure 13). Further to this, it has never experienced declining richness values over consecutive years. Additionally, the lowest levels in EPT richness were seen during a pre-construction year in 2007.

The dominant taxa at station BTH-002 in 2014 was *Gammarus pseudolimnaeus*, a species of Amphipoda belonging to the family Gammaridae. Species belonging to this family occur primarily in shallow waters, resting among vegetation and debris, or slightly within soft substrate. These habitat characteristics are not entirely consistent with the substrates typically found at this site, which are dominated by cobble and gravel. However, some finer sediment was observed in addition to the presence of small amounts of woody debris and detritus, which could provide appropriate habitat for *G. pseudolimnaeus*. *G. pseudolimnaeus* are indicative of very good water quality (Mandaville 2002). This taxa represented 30.0% of the total number of individuals in the sample in 2014 and has been the dominant taxa at this station since 2012 (Figure 14). The result for % dominant taxon has generally been lower at this station over the years of monitoring, with 2007, 2012 and 2014 being relatively high (32.0%, 31.2% and 30.0%, respectively). This site has had five other dominant taxa in the previous eight years of monitoring.

The PMA index in 2014 showed 'no impact' following three consecutive years of 'impact' determinations. Results since pre-construction monitoring began in 2006 have been inconsistent, showing no reliable trend of 'impact' or 'no impact'. 'Impact' has been the most common result, with 'no impact' observed only three out of nine years (2007, 2010, and 2014) (Table 7). While this does represent a threshold exceedance, the predominance of the 'impact' result should not be construed to mean that station BTH-002 is in poorer condition than the other stations. This station is the only station that uses the cobble/gravel model community for PMA index, and it was chosen based on the habitat characteristics of the station. Because of this difference, comparisons among the other 4 stations using the PMA index are not valid. The monitoring program is intended to provide temporal comparison within stations. Refer to Section 5.2.1 for additional discussion of the PMA-analysis threshold exceedances.

<u>Station BTH-003</u>

Taxonomic richness at station BTH-003 was 13 in 2014. This signifies a second consecutive year where taxonomic richness has decreased and a general decrease in richness that began in 2011 (Figure 12), which followed an exceptionally high year in 2010 (n = 42). The results in 2014 are the lowest that has been recorded at this site since sampling began. This result is likely a function of the level of identification of certain groups of the benthic invertebrates, which changed from 2012 to 2013 and continued in 2014. Over the 5 years of monitoring prior to 2011 species richness had increased steadily by 50%, beginning in 2006 with a measure of 21 and increasing to 42 in 2010. The results observed between 2011 and 2013 appeared to be a return to the degree of taxonomic richness that was observed during preconstruction monitoring. While the results in 2014 are below preconstruction numbers, it can likely be explained by the change in the level of identification of some groups in 2013 and 2014. The high richness in 2010 included many taxa in the family Chironomidae. There were numerous individuals in that family in 2014, but they were only identified to the subfamily. This accounts for much of the reduction in taxa richness.

The EPT richness was 0.8% in 2014, a decrease from 6.7% in 2014. This is the first year where EPT richness was below 1.0% and it signifies the lowest proportion of EPT taxa that had been observed at the site to date. Results have varied through the years with an increasing trend observed during the first three years of monitoring and a decreasing trend during the five years prior to 2014 (Figure 13). In 2013 EPT richness increased slightly from 1.9% to 6.7% before declining again in 2014. The EPT richness values seen between 2011 and 2014 show levels that are lower than results from pre-construction monitoring, with the exception of 2013 which saw an increase to pre-construction levels. The decrease experienced between 2013 and 2014 resulted in the exceedance of the threshold for EPT richness (Section 5.2.2).

The dominant taxon in 2014 was *Gammarus pseudolimnaeus*, which comprised 41.2% of the total sample (Figure 14). This marks the third consecutive year that *G. pseudolimnaeus* has been the dominant species at BTH-003. *G. pseudolimnaeus* prefers soft substrates and the shallow areas of both lotic and lentic environments. The preference of this species for depositional areas explains its abundance at station BTH-003 as this station occurs in a slow-flowing area with abundant detritus and underlying substrates dominated by silt and clay. *G. pseudolimnaeus* are indicative of very good water quality (Mandaville 2002). Prior to 2012, the dominant taxon was *Micropsectra* spp. of the order Diptera (true flies).

The PMA analysis showed 'no impact' in 2014. This is a change from 2012 and 2013, both of which showed 'impact' (Table 7). Prior to 2011 the results suggested that habitat and/or water quality conditions at station BTH-003 were generally improving as evidenced by a consistent increase in species diversity (taxonomic richness) and a similarly consistent result of 'no impact'. Results in 2011 and 2012, however, suggested a change in the habitat conditions at this site leading to results that are similar to those observed in 2006. This was demonstrated through a decrease in taxonomic richness and EPT taxa richness, and a large increase in the proportion of the dominant taxon, *Micropsectra* spp in 2011, and *G. pseudolimnaeus* in 2012 and 2013. However, since this change was consistent with pre-construction monitoring results in 2006, it was attributed to natural variation. Results in 2014 show another decrease in taxonomic richness, particularly the EPT richness. At the same time, the dominant taxa is a smaller proportion of the sample, and the PMA analysis returned to 'no impact'. It will be of interest to see if the EPT richness improves in 2015.

<u>Station BTH-004</u>

This was the sixth consecutive year of sampling conducted at this station, which began in 2009. Taxonomic richness at Station BTH-004 was 15 in 2014, which marks a continued decline in taxa richness that began in 2010 with 43 (Figure 12). However, beginning in 2013 this decline was likely a function of the level of identification of the benthic invertebrates, which changed from 2012 to 2013 and continued in 2014. This change is discussed in detail in Section 4.1.3. The results for this metric were relatively high between 2009 and 2011 before they began to decline in 2012.

The EPT richness was 1.3% in 2014, a decrease from 3.9% in 2013 (Figure 13). Although this is not the lowest level that has been observed at this station, it is similar to the low level from 2012, which resulted in a threshold exceedance. Results from 2013 showed a slight recovery in EPT richness values compared to those in 2012. The EPT richness values at BTH-004 have been relatively low in relation to the other four monitoring stations with the highest proportion of EPT taxa occurring in 2009 (12.5%).

The dominant taxon at BTH-004 in 2014 was *Gammarus pseudolimnaeus*, similar to Stations BTH-002 and BTH-003. As noted above, this species generally inhabits the shallow, depositional areas of both lotic and lentic environments within soft substrates and detritus. This is consistent with the habitat characteristics of BTH-004, which is comprised exclusively of fine substrates including silt and sand. Woody debris and detritus are also present throughout the site. This species represented 34.3% of the total sample in 2014 (Figure 14) and was the dominant taxa at this site for the third consecutive year, decreasing in proportion from 56.8% in 2013. Prior to 2012, the dominant taxa was identified as *Caecidotea intermedius*, a species of aquatic sowbug, which dominated the sample in 2010 and 2011. Both *C. intermedius* and *G. pseudolimnaeus* inhabit shallow waters where detritus is present and are likely to coexist in such habitat. *G. pseudolimnaeus* has consistently occurred at this station and represented the second most dominant taxa in 2011.

The PMA analysis showed “impact” at station BTH-004 in 2014 (Table 7). This signifies the third consecutive year of an ‘impact’ determination and an additional year of ‘impact’ following the exceedance of threshold 1 in 2013. This is discussed as a continued threshold exceedance in Section 5.2.1.

Station BTH-005

This was the sixth consecutive year of sampling conducted at this station, which began in 2009. Taxonomic richness at Station BTH-005 was 18 in 2014, a slight increase from

14, which was observed in 2014 (Figure 12). This result is still considerably lower than what was generally observed at this station prior to 2013. A threshold exceedance was observed in 2013 following a decrease from 42, the highest value that has been noted at this site, to 14, the lowest that has been observed. This exceedance was determined most likely to be a function of the level of identification of certain groups of the benthic invertebrates, which was adjusted between 2012 and 2013.

In 2014 the EPT taxonomic richness was decreased from 9.3% to 1.4%, the lowest EPT richness value that has been observed at this station (Figure 13). This resulted in an exceedance of the threshold for EPT richness. This exceedance is discussed in Section 5.2.2. The EPT richness values at BTH-005 have fluctuated since 2006 with no obvious trends observed. The highest results were observed in 2009 and 2012 while low results were observed in 2010, 2011, and 2014. Similar to BTH-004, the EPT richness values at BTH-005 have been relatively low in relation to the other four monitoring stations.

The dominant taxon at BTH-005 was *Gammarus pseudolimnaeus* in 2014, consistent with Stations BTH-002, BTH-003, and BTH-004. *G. pseudolimnaeus* represented 31.6% of the total sample in 2014 (Figure 14). As noted above, this species generally inhabits the shallow, depositional areas of both lotic and lentic environments within soft substrates and detritus. This is consistent with the habitat characteristics of BTH-005, which is comprised of silt and sand along with detritus and some woody debris. Prior to 2014 the dominant taxa had been *Caecidotea* sp., which includes a variety of sowbug species (Asellidae spp.). The occurrence of species belonging to the family Asellidae in a diversity of habitats and their association with groundwater may explain their presence at this station. This taxa was also the second most dominant species in 2014, representing 29.6% of the sample. As seen at the majority of sampling stations, dominant taxa have generally comprised approximately 20% to 30% of the overall sample. Prior to 2014 *G. pseudolimnaeus* was the second most abundant species at BTH-005, representing 21.6% of the total sample in 2013 similar to 2012 when it comprised 10.0% of the sample.

The PMA analysis indicated ‘impact’ in 2014 marking the first year that this determination has been seen. Between 2009 and 2012 the PMA analysis has consistently indicated ‘no impact’ (Table 7).

2.6.2 Fish Community

During 2014 construction-phase aquatic monitoring a total of 454 individual fish were captured representing six different species: Blacknose Dace (*Rhinichthys obtusus*), Brook Stickleback (*Culaea inconstans*), Central Mudminnow (*Umbra limi*), Creek Chub (*Semotilus atromaculatus*), White Sucker (*Catostomus commersonii*), and Pumpkinseed (*Lepomis gibbosus*). The total catch in 2014 experienced a decrease compared to the 2013 assessment, during which 735 fish were caught. The total catch results from 2013 were uncharacteristically high for the project area and results from 2014 signify a trend back towards more 'typical' catches, comparable to what was observed during pre-construction monitoring. Five of the six fish species captured in 2014 are known previously from the monitoring program, with the exception of pumpkinseed, which was captured for the first time. All but one exhibit a cool-water thermal regime, with the exception being Pumpkinseed, which prefers warmer waters (Eakins 2014). Population estimates are provided in Figure 15, and results are discussed below.

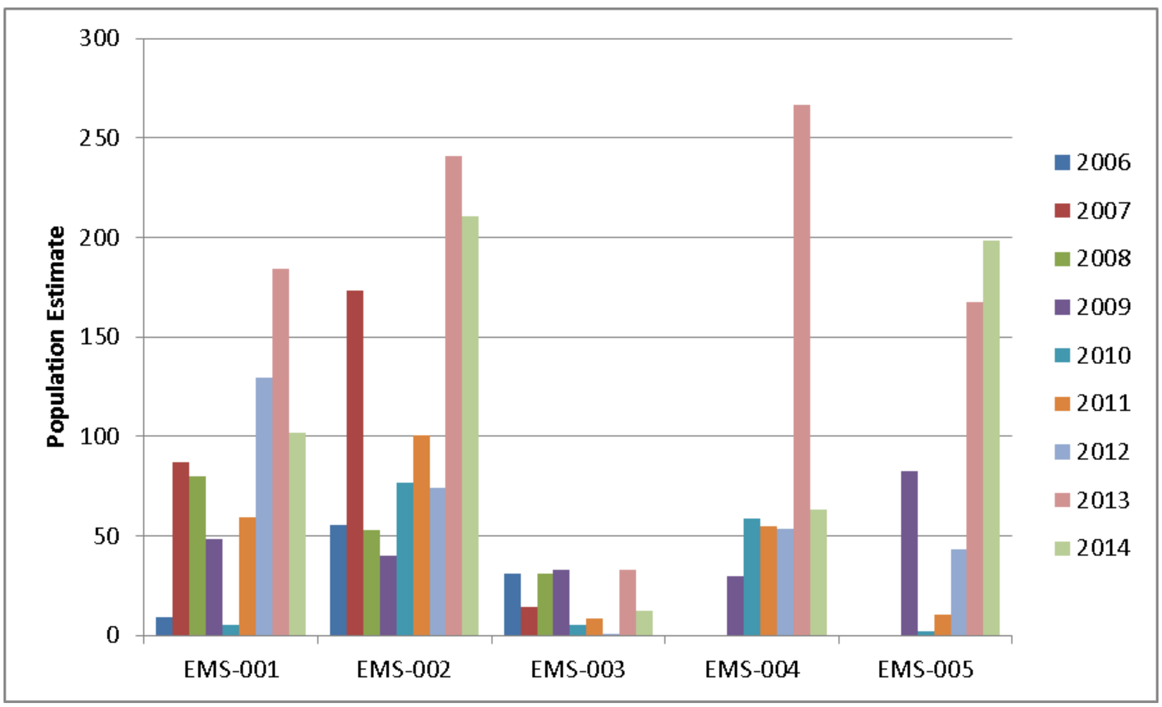


Figure 15. Population Estimates at Electrofishing Stations for the Years 2006 to 2014

Station EMS-001

Electrofishing in 2014 resulted in the capture of four species. They were Blacknose Dace, Brook Stickleback, Central Mudminnow, and Creek Chub. A combined total of 95 individual fish were captured through a total of three passes. White Sucker was captured for the first time at EMS-001 in 2013 but was absent again in 2014. All other species have been captured here throughout previous years of monitoring with Blacknose Dace being captured during every year. Northern Redbelly Dace (*Chrosomus eos*) and Fathead Minnow (*Pimephales promelas*) have also been previously captured at this station (2012 and 2011, respectively) but were absent from sampling in 2014.

Fish population estimates at this station have varied greatly between 2006 and 2014, and have generally been higher during construction-phase monitoring beginning in 2010 than they were during pre-construction monitoring prior to 2010. The decrease observed in 2014 occurred following three years of consistent increases. Increases were observed following 2010, during which the lowest population estimate was observed for this station (approximately 5). Prior to 2010 estimates had decreased consistently, beginning in 2007. The highest estimated population size occurred in 2013 (approximately 184) following a year of above-average precipitation. In 2014 the estimated population size decreased but was still greater than most previous monitoring years.

Station EMS-002

Electrofishing in 2014 resulted in the capture of six fish species and a combined total of 194 individual fish in a total of four passes. The species captured were Blacknose Dace, Brook Stickleback, Central Mudminnow, Creek Chub, White Sucker, and Pumpkinseed. Blacknose Dace and Brook Stickleback have been captured at this station every year while Central Mudminnow and Creek Chub have been captured sporadically over the previous years. White Sucker was captured for the third consecutive year at this station while Pumpkinseed was captured for the first time within the project area. Additionally, Mottled Sculpin (*Cottus bairdii*), a coldwater species that was captured for the first time at this site in 2011 was not captured in 2012, 2013 or 2014. The detailed results are provided in Table 14.

The estimated fish population at EMS-002 has exhibited no obvious trend since sampling began in 2006. The estimated numbers have experienced a great deal of variation with the lowest estimate occurring in 2009 (approximately 40) and the highest estimate of approximately 241 in 2013. In 2014 this estimate decreased slightly but remained well above previous years. The estimated population at EMS-002 was nearly 211, the highest estimate of the five stations sampled in 2014.

Station EMS-003

Electrofishing in 2014 resulted in the capture of two fish species and a combined total of 10 fish over four passes. The species captured were Blacknose Dace and Brook Stickleback. Electrofishing results at this station indicate a low diversity of species relative to the other stations as only two species have been consistently captured here since 2007 (Blacknose Dace and Brook Stickleback). Three species were captured in 2006, which also included Creek Chub.

Population estimates at EMS-003 have been consistently low relative to the other stations within the HCBP study area. The estimate calculated in 2014 signifies a decrease from 2013 but remains similar to previous years` estimates and remains above the lowest estimates observed between 2010 and 2012.

Station EMS-004

Electrofishing took place at this site for the first time in 2009 and it has been sampled every year since. Electrofishing in 2014 resulted in the capture of four fish species and a combined total of 51 individual fish in three passes. The species captured included Backnose Dace, Brook Stickleback, Central Mudminnow, and Creek Chub. These four species have been consistently captured over the previous years of monitoring. White Sucker was captured at this station for the first time in 2013 but was not captured during 2014 sampling.

Fish population estimates remained relatively consistent at EMS-004 between 2009 and 2012 ranging from approximately 29 to 58. In 2013 the population estimate increased substantially to 266, the highest estimate recorded at any of the five stations since sampling began in 2006. In 2014 the estimate decreased to approximately 63, comparable to sampling results prior to 2013.

Station EMS-005

Electrofishing took place at this site for the first time in 2009 and has been sampled every year since. Electrofishing in 2014 resulted in the capture of five fish species and a combined total of 104 individual fish over three passes. The species captured included Blacknose Dace, Brook Stickleback, Central Mudminnow, Creek Chub, and White Sucker. Prior to 2013, this station typically contained between two and three species. In 2013, seven species were captured including fathead minnow and Northern Redbelly Dace, which were not captured in 2014. Blacknose Dace has been captured during every year of sampling at this station. Brook Stickleback, Central Mudminnow and Creek Chub have also been captured throughout previous years of monitoring.

The population estimate at station EMS-005 in 2014 was approximately 198. This is the highest population estimate that has been observed at this station since sampling began in 2009. This also marks the fourth consecutive year that the population has increased at this station since it reached a low of approximately two in 2010, with the result that the population is higher than any previous year at this station. Additionally, this is the only station in 2014 that observed an increase in estimated population size compared to 2013.

2.7 Terrestrial Habitat and Biota

Since 2006, the terrestrial and wetland monitoring program has focused on plot-based surveys to document breeding amphibians, breeding birds and vascular flora (herbaceous, shrubs and trees) as well as incidental wildlife throughout the property. Soils information was collected from each of the monitoring plots between 2006 and 2014.

For plot set-up and annual monitoring survey methods, the reader is referred to the HCBP Terrestrial and Wetland Monitoring Report (Appendix V). In addition, the Standard Operating Procedures for the vegetation, breeding birds and amphibians are found in the *HCBP Consolidated Monitoring Program* (NRSI 2010). The monitoring stations are shown on Map 6 of this report.

Detailed results for the terrestrial habitat and biota are given in the 2014 terrestrial and wetland monitoring report prepared by NRSI (Appendix V). The results are summarized and discussed below.

2.7.1 Vegetation and Soils

In 2014, a total of 136 vascular flora species were documented during the plot-based monitoring. Overall, 248 different species have been observed in the vegetation monitoring plots. In 2014, vegetation surveys documented three species not previously recorded: Wool-grass (*Scirpus cyperinus var. cyperinus*) and Redtop (*Agrostis stolonifera*) in Plot 6, and a Bur Oak (*Quercus macrocarpa*) sapling in Plot 7.

A total of 12 regionally significant species have been observed in the plots between 2006 and 2014. In 2014, Meadow Horsetail (*Equisetum pratense*) and Rough-leaved Goldenrod (*Solidago patula*) were observed and are considered rare within Wellington County. None of the species observed are federally or provincially significant.

Refer to Map 6 for locations of vegetation monitoring stations, and the 2014 terrestrial and wetland monitoring report (Appendix V) for a comprehensive list of the vegetation species observed from 2006 to 2014.

2.7.1.1 Floristic Indices

A common method for evaluating and assessing natural areas is using floristic composition. This method is based on the character of a region's flora. There are several floristic indices which can be used to describe the character of the vegetation in the plot. These include the Coefficient of Wetness (CW), the Coefficient of Conservatism (CC), and the Natural Area Index (NAI). All species (herbs, shrubs, and trees) from each plot are considered in these equations.

<u>Coefficient of Wetness</u>

The CW is based on wetland values given to each individual plant species. Values range from -5 to +5, where -5 indicates an obligate wetland species, and +5 indicates an obligate upland species. "0" is assigned to facultative species, those that are just as likely to be found in wetland or upland habitats. The CW values used are based on Oldham et al. (1995). Figure 16 shows the average wetness per plot, based on the wetness coefficients of all species found within a plot. All except two of the monitoring plots are located within wetland areas.

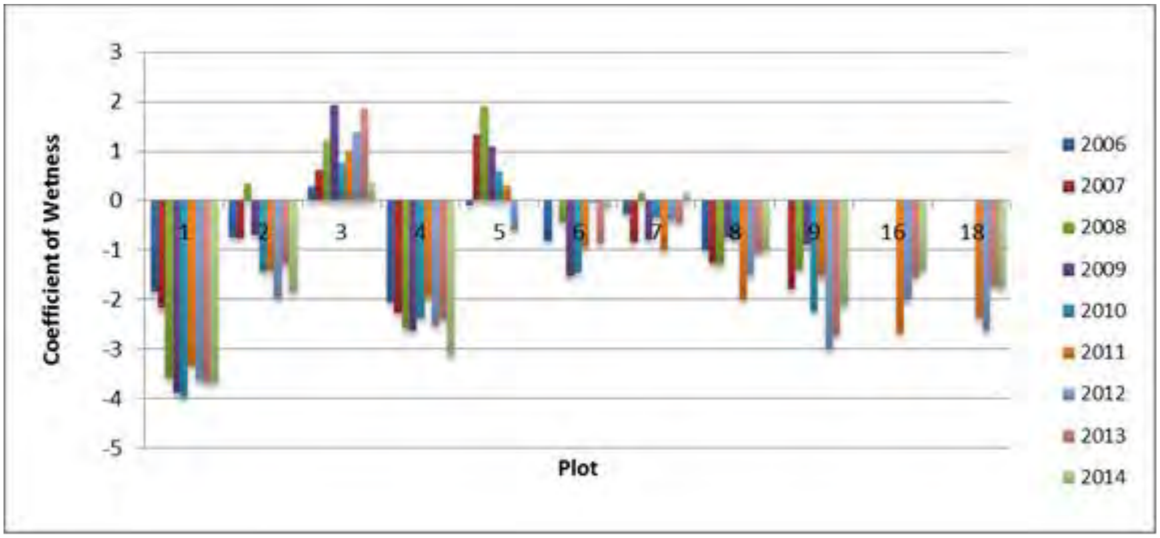


Figure 16. Coefficient of Wetness by Plot 2006 - 2014

Plot 1 continued to be the wettest plot, with an average CW score of -3.67 in 2014. Shallow, pooled water is regularly present throughout much of Plot 1 at the time of the vegetation survey. This plot supports a variety of facultative wetland shrubs and herbaceous species. Plot 3 (Sugar Maple forest) continued to exhibit the driest average CW value (0.38). Only two vegetation monitoring plots occur within upland ELC communities (Plot 3 and Plot 5); however in 2014 Plot 7, located within a White Cedar-Hardwood mixed swamp exhibited a positive average CW value. This plot had a positive CW value in 2009 and generally has an average CW value between 0 and -1. It is noted that the plot contains hummocks which allow for a diversity of upland and wetland herbaceous species. The remaining eight plots are located within swamp or marsh habitat.

At Plot 16 and Plot 18, CW values have shown a drying trend between 2011 and 2014, with 2013 and 2014 CW values being similar. These plots are located in close proximity to recent development (Block 9 and Block 10) and the Hanlon Creek Boulevard (Maps 2 and 6). Both of these plots were added in 2011 to monitor any changes within the wetland community due to the potential dewatering required as part of the City of Guelph SW Quadrant Class EA.

Plot 16 has consistently contained limited herbaceous vegetation, and is located in a wetland that is physically separate from the core PSW but considered part of the Hanlon Swamp Wetland Complex. Groundwater levels at Plot 16 do not correspond to the drying trend in CW values. Contour mapping shows that its elevation ranges from 324m to 325m above mean sea level (amsl). Monitoring well MW103 is located adjacent to this wetland where ground elevation is approximately 234m amsl. The continuous data logger has recorded groundwater elevations ranging from a low of just over 322.0m amsl in 2012 to 323.5m amsl in the spring of 2013. This demonstrates that the ground water is near the surface, yet the continuous data logger at MW103 has not measured levels at or above the ground surface since its installation in the summer of 2010. In 2014, the level at MW103 reached 323.4m in April and September. Since 2012, groundwater levels at MW103 appear to be similar to or higher than levels from 2010 to 2012. Thus, groundwater levels in the vicinity of Plot 16 do not show a trend that matches the trend in CW values.

Plot 18 has contained a diversity of species with good coverage of the 10x10m plot. It too is located in a small wetland that is physically separate from the core PSW but considered part of the Hanlon Swamp Wetland Complex. Similar to Plot 16, groundwater levels at Plot 18 do not correspond to the drying trend in CW values. Contour mapping shows that its elevation is +/1 324m amsl. Monitoring Well MW118A is located approximately 80m south of this wetland and occurs where the ground elevation is also at an elevation of approximately 324m amsl. The continuous data logger has recorded groundwater elevations ranging from a low of just over 322.5m amsl in August 2011 to a high of just over 323.9m amsl in February 2009. In 2014, there was a low elevation of just under 322.9 in July and a high of almost 323.9m amsl in September. A similar low of 322.6m amsl occurred in July/August 2012. Since installation of the monitor in the summer of 2008, the groundwater at MW118A seemed to be highest in 2009, lowest in the summers of 2011 and 2012, and moderate in 2013 and 2014. This demonstrates that the ground water at MW118A can be near the surface, but often ranges from 0.5 to 1.0m below surface, and even lower at times. The low groundwater levels in the summers of 2011 and 2012 may be associated with the drying trend in CW values at Plot 18; however, the results from the years 2013 and 2014 do not demonstrate dry conditions that would easily explain the continued drying trend.

Plot 9 (cattail marsh) had shown decreasing CW values, indicating a trend of becoming wetter; however average values in 2013 (-2.71) and 2014 (-2.09) have demonstrated a return to values observed prior to 2012 when the average CW was -3.00. This plot is located in a reed-canary grass marsh and was originally added to the monitoring program to track changes as a result of the Mast-Snyder Gravel Pit to the west of the subject property. The Mast-Snyder Gravel Pit project has not been initiated; therefore, trends being observed within Plot 9 are likely attributed to natural fluctuation in precipitation from year to year. Additionally, the observation of certain species in one monitoring year (but not the next) can influence these values, such as Dark Green Bulrush (Scirpus atrovirens), that was observed in 2012 but has not been recorded since. With a CW of -5, species such as this would impact the overall CW value for the plot; conversely, the observation of a species with a high CW value among low CW species would influence the overall average. Plots which contain a low diversity of species are more susceptible to data fluctuations as the addition or removal of a single species can significantly impact calculations. As the average CW does not account for abundance and only provides an analysis of the overall species list, outlier species can inflate average CW values for low diversity plots.

<u>Coefficient of Conservatism</u>

Species conservatism is the degree of faithfulness a plant displays to a set of environmental conditions. The quality of a natural area is reflected in the number of conservative species found within a certain habitat (Wilhem and Ladd 1988 *In* Oldham et al. 1995). For the CC, each species is given a rank between 0 and 10, based on its degree of fidelity to a range of synecological parameters (Oldham et al. 1995). Synecology is the study of the structure, development, and distribution of ecological communities. Species ranked between 0 and 3 are found in a variety of plant communities, including disturbed sites. Species ranked between 4 and 6 are those associated with a specific plant community, but which can tolerate moderate disturbance. Species ranked from 7 to 8 are found in plant communities in an advanced stage of succession with minor disturbance. Plants with a ranking of 9 or 10 have high degrees of fidelity to a narrow range of synecological factors.

The average CC per plot is shown on Figure 17. The highest CC value in 2014 was found in Plot 1 (4.76), which is within a Slender Willow thicket swamp (SWTM3-3). Plots 1 through Plot 4 and Plot 7 all exhibited average CC values between 4 and 5 in 2014 and are consistently among the highest values from year to year. Species such as Meadow Horsetail and Swamp Thistle (*Cirsium muticum*), both with a CC value of 8, provide an indication of the high quality habitat found in Plot 1 and Plot 2 respectively. The lowest average CC values continue to be found in Plot 6 (2.24), a Reed Canary Grass meadow marsh (MAMM1-3) as well as Plot 9 (2.60), a Cattail shallow marsh (MASM2-1). Neither of these plots contain trees and are likely to have been cleared and farmed historically given the presence of non-native species and their proximity to existing (or previously existing) farm fields. These plots are dominated by early successional herbaceous species, most of which have a low CC value or no CC value for those species considered non-native to Ontario.

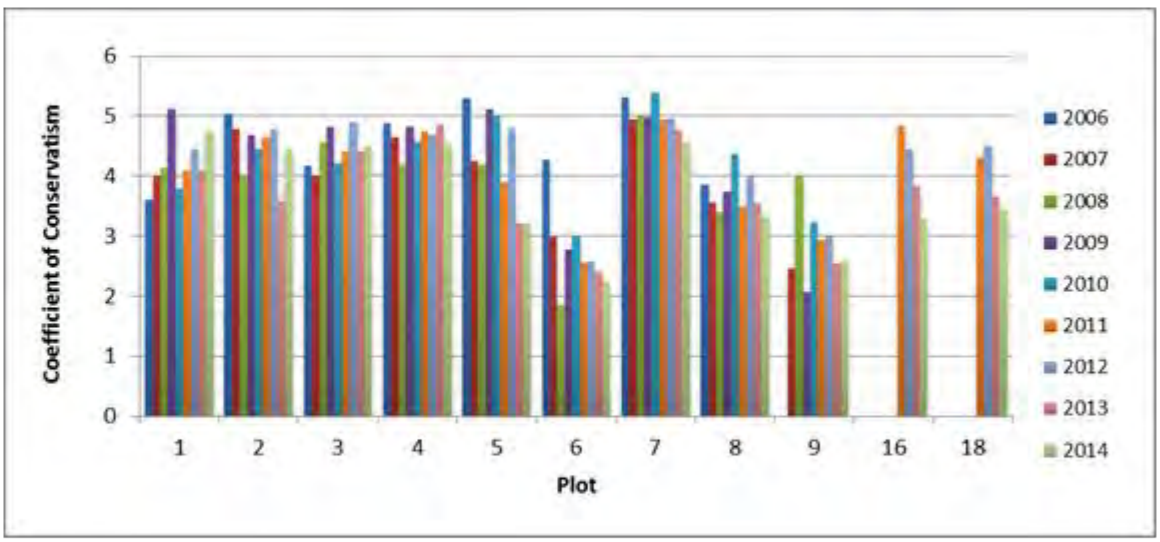


Figure 17. Coefficient of Conservatism by Plot 2006- 2014

In most plots, the average CC value has shown minimal variation between 2006 and 2014. It should be noted that the recording of a single species with an exceptionally high or low CC value (particularly within a plot containing a relatively small number of species) can influence average CC values greatly. The decrease in average CC values in Plot 5 (17.71 in 2009 and 7.16 in 2014) may be attributed to this factor. It is believed that the variation being documented within the CC continues to be largely a result of natural fluctuations within the system including annual climate fluctuations, succession and seed dispersal and establishment.

The decrease in average CC value within Plot 16 is attributed to the disappearance of species observed in 2011 which have high CC values including Common Skullcap (*Scutellaria galericulata*), Tufted Loosestrife (*Lysimachia thyrsiflora*) and Meadow Horsetail (CC values of 6, 7 and 8 respectively). A decrease in soil moisture within the plot has likely altered the site suitability for these species which have not been observed since 2011. The very low amount of springtime precipitation in 2012 may be partially responsible for the disappearance of species with high site fidelity. There is potential that species which have disappeared from a plot may re-appear in later years through the germination of the seedbank or recolonization from areas adjacent to the plot where the plants may persist.

Natural Area Index

The NAI, or floristic quality index, allows the objective comparison of two or more natural areas or vegetation types (Oldham et al. 1995). The NAI is calculated by multiplying the average CC value by the square root of the total number of native species. Whereas the abundance and frequency of species can fluctuate greatly by season and year, the NAI is more stable and offers a more accurate picture. The NAI for each plot is shown on Figure 18.

The Ministry of Natural Resources and Forestry (MNRF) reports that natural areas with NAI values of over 35 are considered significant at the provincial level (Wilhelm and Ladd 1988 in MNR 1994). For comparison, an old successional field may score as low as <5 (Andreas et al. 2002). None of the plots within the HCBP score a value of 35 or higher. In 2014, 5 of the 11 vegetation monitoring plots were equal to or showed slight increases in NAI over 2013 values; however overall values are still generally lower than in previous years. Figure 18 shows that NAI values peaked in the during construction monitoring years 2010 and 2011.

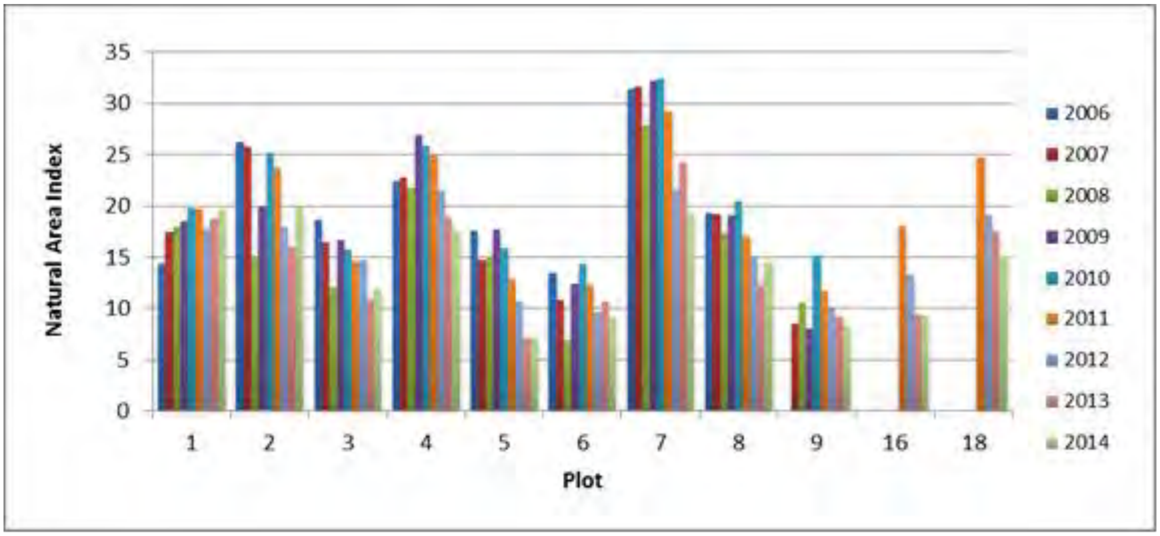


Figure 18. Natural Area Index by Plot 2006 – 2014

In 2014, the highest NAI value of 19.90 was found in Plot 2 (White Cedar – Coniferous Swamp – SWCO1-2), which is roughly average for the plot between 2006 and 2014. A high value of 26.20 was documented for the plot in 2006 with a low value of 14.97 in 2008 (both baseline monitoring years). As discussed above for CW and CC values, the addition or subtraction of a few species can have great bearing on the overall NAI value. A number of factors will influence the parameters of the NAI equation (average CC and number of native species). Some factors include plant senescence or mortality due to drought (i.e. 2012). Given that most of the vegetation monitoring plots are located within wetlands, it is likely that the dry conditions in 2012 had a lingering effect on vegetation composition. Some species may re-appear in time through the seed bank or colonization from areas adjacent to the plot. It is also possible that species that were observed in very limited numbers, such as White Beaked-rush (*Rynchospora alba*) (CC 10) in Plot 8 in 2012 may not re-appear in the near future.

The lowest NAI values in 2014 were observed in Plot 5 (7.16), Plot 6 (9.22) and Plot 9 (8.22). Each of these values can be attributed to different factors. The very low species diversity in Plot 5 had produced higher NAI values between 2006 and 2009 before a drop to present values. Meadow Horsetail (CC 8) was observed only in the two years which had the highest NAI for the plot; 2006 and 2009. Within a low diversity plot such as this, the influence of a single species has a notable bearing on NAI values.

Plot 6 exists within an old field meadow which contains non-native species and early successional species. The absence of high CC species within the plot maintains a low NAI value at this location. Plot 9 is dominated by Reed Canary Grass (CC 0) with abundant Broad-leaved Cattail (*Typha latifolia*) (CC 3). With the exception of Common Buckthorn (*Rhamnus cathartica*), the plot contained all native species in 2014; however the dominance of a Reed Canary Grass and Broad-leaved Cattail produces a consistently low NAI value.

As noted in the 2013 monitoring report, the effects of the extremely dry spring in 2012 are likely to have lingering effects on the diversity of plants throughout the site. Further monitoring will determine to what degree.

2.7.1.2 Non-Native Species

A total of 16 non-native species were recorded within vegetation plots in 2014. The number of non-native species found in each plot is compared on Figure 19. In general, non-native species have been present in all plots over the course of monitoring with the exception of Plot 5, a low diversity plot within which Helleborine (*Epipactis helleborine*) is present in very low numbers in some years but not others. The greatest number of non-native species was recorded in Plot 6, with 9 species documented. In 2010, 15 non-native species were documented within this plot, a number which has declined every year since. In general, the same aggressive non-native species have been observed between 2006 and 2014. Situated within a successional reed canary grass meadow marsh, Plot 6 has consistently contained a high number of non-native species due to historic disturbance (human disturbance from ATV's/machinery during pre-construction monitoring year) and close proximity to the previous agricultural land use. Non-native species such as Quack Grass (*Elymus repens*), Coltsfoot (*Tussilago farafara*) and Bird's-foot Trefoil (*Lotus corniculatus*) are clonal, somewhat aggressive and will likely continue to exclude higher quality plant species from establishing until tree canopy develops and the area is in an advanced state of succession.

The non-native species observed in 2014 do not represent any significant introductions or reductions of aggressive non-native species. Plot 2 has shown an increase in non-native species while Plot 9 has shown a decrease. In general, those species with weediness values of 2 or 3 tend to be present year after year, while less invasive species with a value of 1 are present intermittently and often in low numbers.

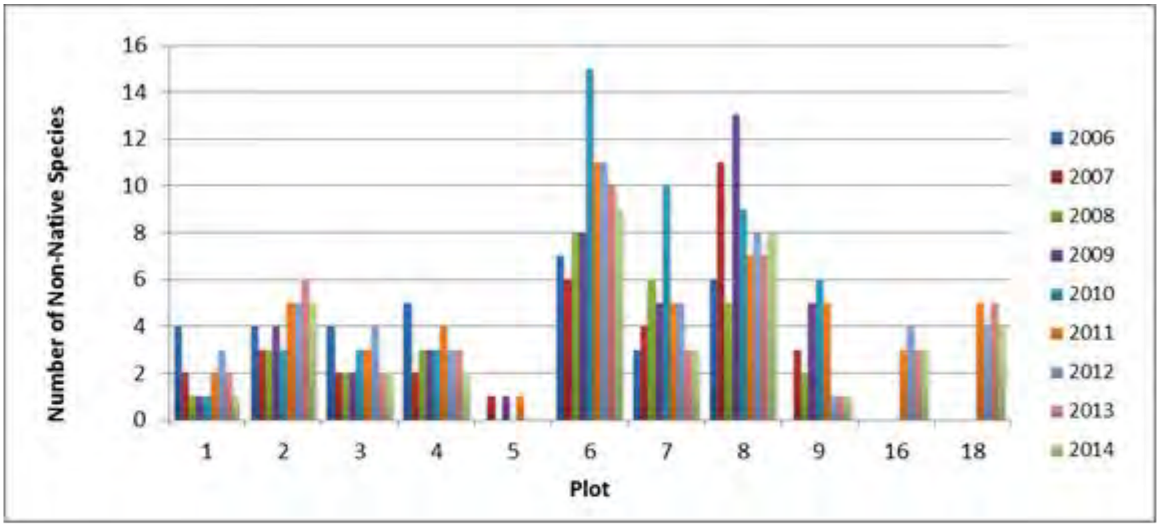


Figure 19. Non-Native Species by Plot 2006 - 2014

Between 2006 and 2013, 29 other non-native species were recorded that were not observed during the 2014 surveys. This fluctuation suggests that some non-native species may only establish for a single season before ecosystem resilience, site conditions (including drought or flooding), or a combination of both suppress the species from establishing within the plots permanently.

Certain non-native species are considered particularly invasive, and are given a score of '-3' on a weediness scale ranging from '-1' to '-3'. The invasive species found within the HCBP vegetation monitoring plots include 4 shrub species (3 species with a weediness value of -3) and 12 herbaceous species (all species with a weediness value of -2 or -1).

Garlic Mustard (*Alliaria petiolata*) was only recorded in Plot 18 during the 2011 monitoring year. This species is very common and invasive and it is rare to find areas that do not contain this plant. Most of the non-native species present within the monitoring plots are common agricultural weeds or shrub species which produce prolific amounts of berries that are distributed by deer, birds and other wildlife.

Common Buckthorn is the most widely dispersed non-native plant within the monitoring plots, with Glossy Buckthorn (*Rhamnus frangula*) also found in a number of plots with mesic to wet soils. Both species are tolerant of shading and fruiting specimens tend to be most common at the edge of wooded features where they receive ample sunlight. Due to the ability of these species to grow beneath a dense canopy, a groundcover of herbaceous vegetation is often interspersed with many young seedlings which germinate from the seedbank. Common Buckthorn is widespread throughout southern Ontario; it is often found on calcium-rich soils and occurs in a range of soil moisture and sunlight conditions (Anderson 2012).

During vegetation surveys some species were only identified to genus as the identifying traits of the plant may not have been apparent at the time of the survey. These include Avens Species (*Geum sp.*), Sedge Species (*Carex sp.*), Smartweed Species (*Polygonum sp.*) and unidentifiable grass species. These species were included in the overall species count for the plot but were not included in the non-native species totals as a positive identification of the species was not possible.

2.7.1.3 Herbaceous Inventory

A total of 103 species of herbaceous plants were observed during the plot-based vegetation monitoring that was conducted in 2014, two of which were recorded for the first time in 2014. The three new species – Redtop, Wool-grass and Bur Oak – are all native and prefer wetland or bottomland habitat.

2.7.1.4 Shrub Inventory

In 2014, 22 shrub species were recorded. This number has varied over the monitoring years with low values of 15 species recorded in 2007, 2008, and 2009. All shrub species documented within vegetation monitoring plots had been noted in previous years with no new species additions in 2014.

2.7.1.5 Tree Inventory

Results from the 2014 are provided in the 2014 terrestrial and wetland monitoring report. Similar to previous monitoring years, no tree species are present within Plots 1, 6 and 9. In general, the composition of tree species has remained the same throughout the monitoring period. No notable changes were observed in tree species composition or tree health within any of the monitoring plots between 2014 and previous years.

While signs of Emerald Ash Borer (*Agrilus planipennis*) (EAB) were not noted in 2013 or 2014 monitoring, it is very likely that the insect is present within the subject property and widespread decline of Ash (*Fraxinus* spp.) trees, including those within monitoring plots, may be inevitable. A total of 9 Ash trees are tagged and were monitored in 2014; of these, 5 are in decline, 1 is a snag and 3 are actively growing. These comprise Black Ash (*Fraxinus nigra*), White Ash (*F. americana*) and Green Ash (*F. pensylvanica*) growing in Plots 2, 3, 4, 7 and 18. A loss of canopy cover due to Ash decline is likely to make for a temporary increase in herbaceous species both in numbers and in vigour. In time the canopies of existing trees including White Cedar (*Thuja occidentalis*), Red Maple (*Acer rubrum*) and Yellow Birch (*Betula alleghaniensis*) will fill in those areas where Ash was once present. Canopy openings will also spur the growth of shrub and tree saplings.

2.7.2 Breeding Birds

2.7.2.1 Breeding Bird Species Diversity

During 2014 monitoring, a total of 42 species of birds were observed during the point counts at the monitoring plots. Including those species which were noted outside of point counts or incidentally during other surveys, a total of 51 bird species were documented within the study area in 2014. Of the 42 species observed during the formal point counts, 15 exhibited possible breeding evidence, 23 exhibited probable, two were confirmed, and two did not show breeding evidence.

The most abundant species observed during 2014 surveys were Red-Winged Blackbird (*Agelaius phoeniceus*), and American Robin (*Turdus migratorius*), both with 11% of the observations during breeding bird point counts. These were followed by Song Sparrow (*Melospiza melodia*) at 9%, and five other species with proportions of 4% to 6%. These species are consistently the most abundant within the point counts largely due to the presence of suitable habitat and the large populations of these species within southern Ontario. Figure 20 represents the nine most abundant species observed in 2014, with all other birds observed less frequently lumped together in ‘other’.

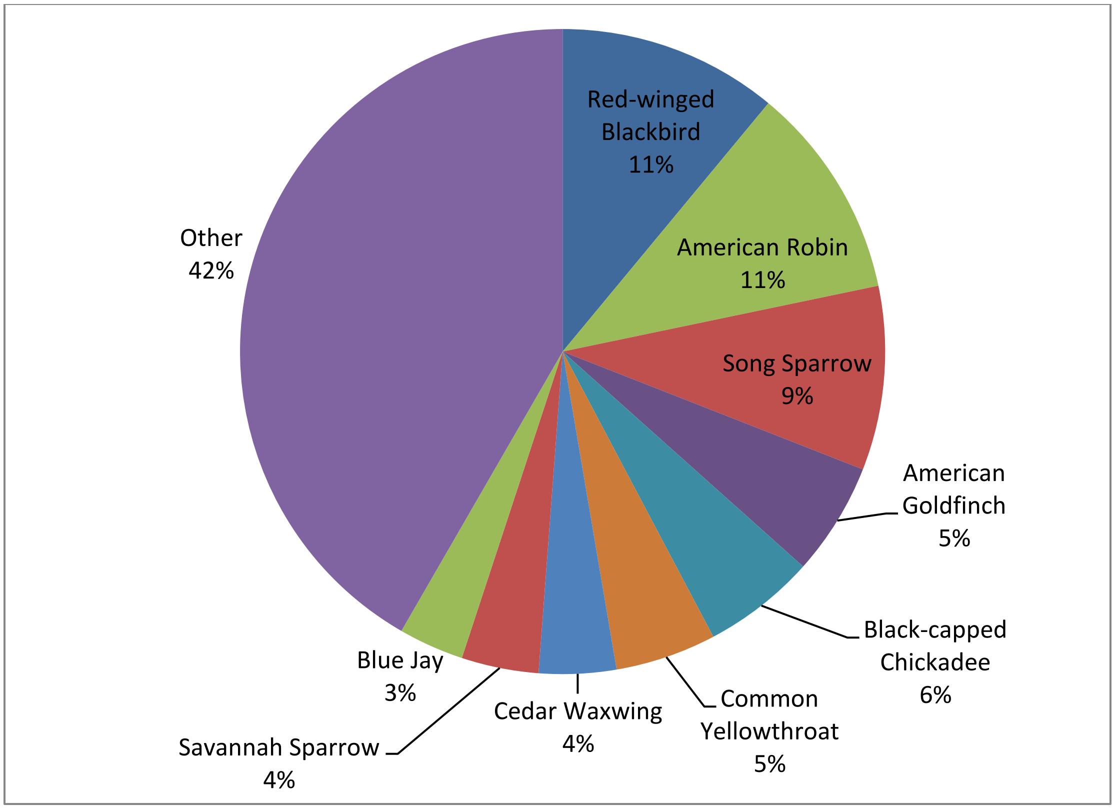


Figure 20. Most Abundant Bird Species Observed in 2014

In 2014, two bird species new to the site were recorded either during breeding bird surveys or incidentally. These species included Green Heron (*Butorides virescens*) and Solitary Sandpiper (*Tringa solitaria*). Green Heron was recorded as a fly-over and did not exhibit any signs of breeding. Solitary Sandpiper was documented incidentally as showing probable breeding evidence near Plot 7. While mud flats and fringes associated with SWM ponds on site may provide suitable foraging habitat for this species, the known breeding range in Ontario exists within boreal forests of the north (Moskoff 2011, BSC 2015). It is likely that this species was a migrant and did not breed on site in 2014. In addition, the regionally significant Black-billed Cuckoo (*Coccyzus erythropthalmus*) was documented as showing breeding evidence (probable) within the subject property for the first time in 2014; it had been observed in previous years but not showing any signs of breeding.

In general, the diversity of bird species at each plot in 2014 was similar to those numbers documented between 2006 and 2011, with 2012 and 2013 appearing as exceptional years of high diversity across the study area (Figure 21).

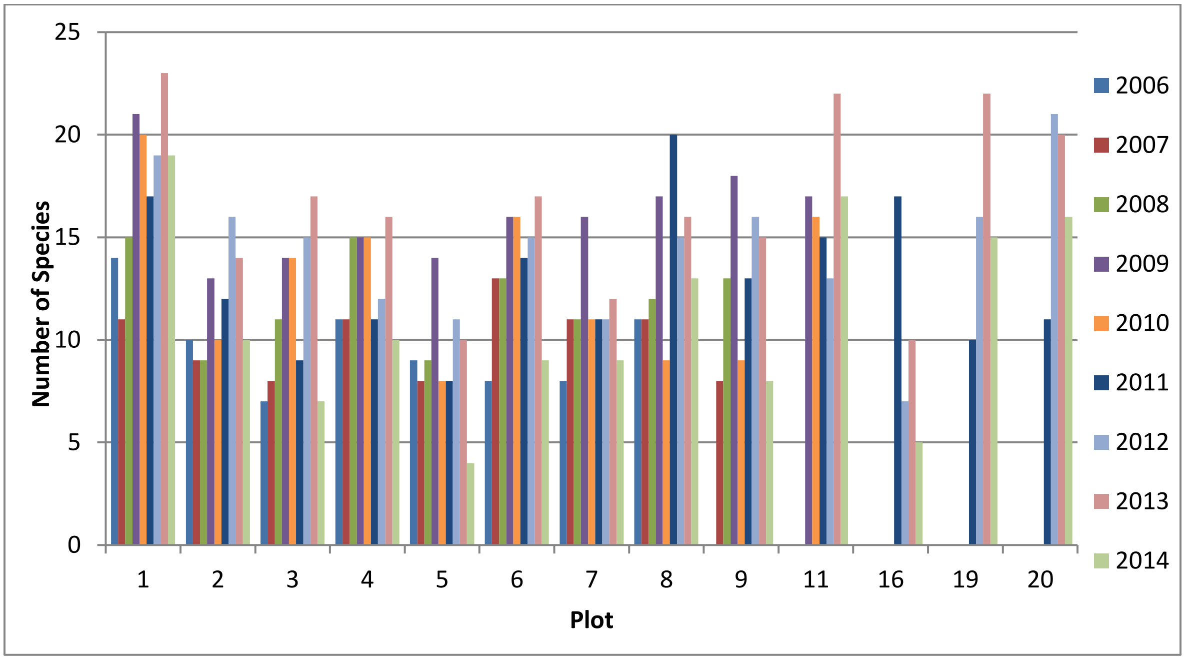


Figure 21. Breeding Bird Species Diversity 2006 – 2014

The breeding bird survey results have been of particular interest at several plots for the last three to five years. Plot 11 had decreasing species diversity from 2009 to 2012, followed by a rebound in 2013 and a moderate result of 17 species in 2014.

Plot 16 has had relatively low bird species diversity since it was established in 2011, with a result of only five species in 2014 compared to 17 in 2011. Ongoing construction to the east in Blocks 9 and 10 is the likely reason for the low diversity, and it will likely continue until construction of the buildings is complete and edge plantings are established. A naturalizing meadow to the south is also likely to benefit species diversity in the future.

The species diversity at Plots 19 and 20 had previously increased since 2011 in conjunction with succession of the old field habitat, and then it decreased somewhat in 2014. These plots are located in Phase 3 which has not yet been developed. The decrease in species diversity in 2014 was moderate, and there were once again observations of three Species at Risk. Bobolink (*Dolichonyx oryzivorus*) showed probable breeding evidence, Eastern Meadowlark (*Sturnella magna*) showed possible breeding evidence, and Barn Swallow (*Hirundo rustica*) was observed as a fly-over with no breeding evidence. Song Sparrow and Savannah Sparrow (*Passerculus sandwichensis*) remained abundant within the open country plots in Phase 3, both showing probable breeding evidence.

2.7.2.2 Breeding Bird Abundance

The breeding bird abundance (the number of individual birds) since 2006 is shown on Figure 22. In general the 2014 abundance reflects the overall average since monitoring began in 2006. Similar to species diversity, breeding bird abundance showed a notable spike during the 2012 and 2013 monitoring years and 2014 data reflects abundance data observed between 2006 and 2011. Those species which have tended to comprise much of the abundance value for each plot including Red-winged Blackbird, American Goldfinch, Song Sparrow, Black-capped Chickadee and American Robin continue to comprise the bulk of individuals observed. Spikes in bird abundance have been observed in past monitoring years due to large flocks of a single species which have included Red-winged Blackbirds in Plot 6 in 2006 and Canada Goose (*Branta canadensis*) in Plot 9 in 2007.

Plots 1 and Plot 6 continue to have among the highest bird abundance (51 and 33 respectively); however Plot 20 has also shown high abundance since 2012. These plots are likely to yield higher bird abundance due to a combination of treed and open upland and wetland habitats present within the immediate survey area. Those plots which consistently show the lowest bird abundance, particularly Plot 5 are situated well within wooded features and are thus less likely to have species that prefer edge or open country habitat. Comprised largely of White Cedar and lacking understorey or groundcover vegetation, only 8 birds were documented in Plot 5 during breeding bird surveys in 2014.

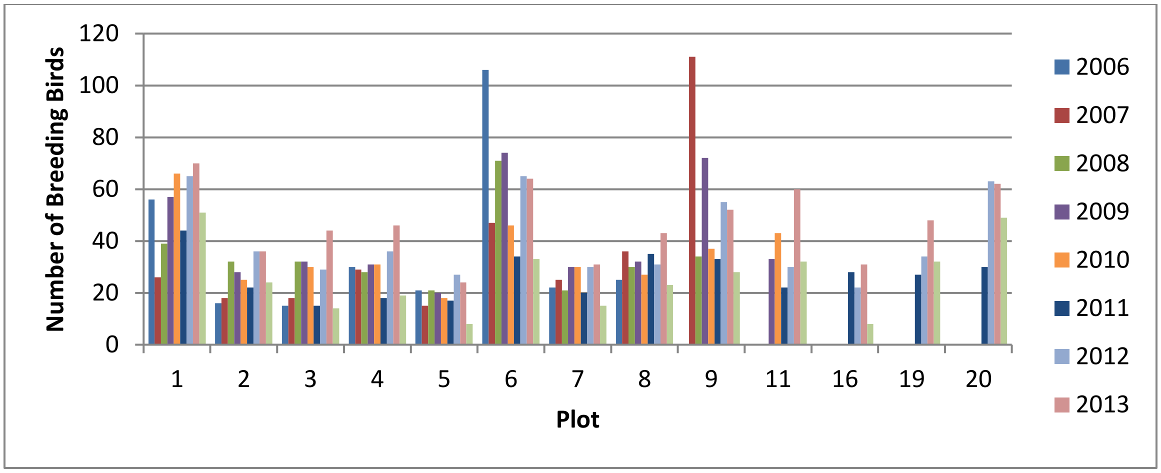


Figure 22. Breeding Bird Abundance 2006 - 2014

2.7.2.3 Significant Species

NRSI observed three species that are considered Threatened federally and provincially (Government of Canada 2015, MNRF 2015): Barn Swallow, Bobolink, and Eastern Meadowlark. Bobolink was listed as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and the Committee on the Status of Species at Risk in Ontario (COSSARO) in 2010, while Barn Swallow and Eastern Meadowlark were up-listed in 2011. Bobolink requires large, open expansive grasslands (>50ha) with dense ground cover; hayfields, meadows or fallow fields; marshes (OMNR 2000). This species has been observed each monitoring year with probable breeding evidence documented in 2010 and 2012 through 2014. In 2014, Bobolinks were observed only within Plot 20.

Barn Swallows are found in farmlands and rural areas, and generally use buildings (such as barns) or other man-made structures for nesting. They are often found foraging in open country near water (Brown and Bomberger-Brown 1999, OMNR 2000a). In 2014, this species was recorded as a fly-over for Plots 9, 19 and 20. The Crawley farmhouse which exists near Plot 20 may provide suitable nesting habitat for Barn Swallow; however, no breeding evidence was observed at Plot 20 or within the subject property in 2014. Barn Swallow may also be nesting outside of the subject property in barns along Forestell Road or Downey Road and utilizing the subject property for foraging habitat.

Eastern Meadowlark requires grassy meadows, farmland, pastures or hayfields at least 10ha in size (OMNR 2000). Suitable habitat for these open country birds is found within the southwest portion of the subject property (Phase 3) as well as within the retained open meadow habitat associated with Plot 19 (Map 6). This species was recorded as showing possible breeding evidence in 2014 and has been recorded showing possible or probable breeding evidence on site every year since 2007. As noted in previous monitoring reports, the establishment of old field meadow throughout Phase 3 is providing suitable breeding habitat for open country breeding bird species.

Eastern Wood-Pewee (*Contopus virens*) is listed as Special Concern federally and provincially (Government of Canada 2015, MNRF 2015). Eastern Wood-Pewee prefers open forest (deciduous, coniferous or mixed) often predominated by oak with little understory or forest clearings, edges, farm woodlots or parks (OMNR 2000). A single singing male was observed at Plots 2, 11 and 19 during the June 7, 2014 survey with a single singing male at Plots 2 and 19 during the second visit denoting probable breeding evidence. Given that a single bird was observed at 3 plots in close proximity, it is possible that the same bird was observed/heard at multiple locations and on multiple survey dates.

A total of 15 bird species were observed which are considered significant within the City of Guelph (Dougan & Associates 2009). Of these 15 species, one showed confirmed breeding evidence: Belted Kingfisher (*Megaceryle alcyon*) at Plot 8. A total of seven species showed probable breeding evidence, including Baltimore Oriole (*Icterus galbula*), Bobolink, Savannah Sparrow (*Passerculus sandwichensis*), Rose-breasted Grosbeak (*Pheucticus ludovicianus*), American Redstart (*Setophaga ruticilla*), Willow Flycatcher (*Empidonax traillii*) and Black-billed Cuckoo. Additionally, three species showed possible breeding evidence, and four did not show any breeding evidence (i.e. flying over habitat). Significant species within Wellington County which were not previously recorded within the subject property included Green Heron (*Butorides virescens*) and Barred Owl (*Strix varia*).

2.7.3 Amphibians

Calling anuran species were recorded at 12 of 16 monitoring plots in 2014. Three species of anuran were documented at Plots 1 and 16. No calling anuran species were documented in 2014 at Plots 7, 8, 10 and 13. These plots generally lack standing water and do not provide ideal anuran breeding habitat.

Five amphibian species were recorded during evening call count surveys in 2014; Spring Peeper (*Pseudacris crucifer crucifer*), Wood Frog (*Lithobates sylvatica*), Northern Leopard Frog (*Rana pipiens*), Green Frog (*Rana clamitans melanota*) and Gray Treefrog (*Hyla versicolor*). Since 2006, the number of species recorded during the calling anuran surveys has fluctuated. The five amphibian species recorded calling in 2014 is above the annual average of 3.6 species recorded in previous years. Species recorded during surveys have fluctuated over the eight-year monitoring period, with as many as six species recorded during 2009 surveys and none recorded during the first preconstruction monitoring year (2006).

Spring Peeper was the most abundant anuran in 2014. It was recorded at eight of the 16 anuran monitoring stations, and there was a full chorus of many individuals at Plots 1 and 9. They were recorded for the first time in Plots 14 and 17 in 2014.

Green Frog was heard calling in low numbers at Plots 4 and 15, with an estimate of 7 calling individuals on June 9. Green Frog has been documented sporadically between 2007 and 2014 in low numbers.

Gray Treefrog was the second-most widely distributed species in 2014. It was recorded at six of the 16 anuran monitoring stations, and was recorded in high numbers at Plot 1 in both 2013 and 2014. Plot 1 is part of a willow thicket swamp that is subject to seasonal flooding.

Wood Frog had notably low numbers heard calling in 2014. A single individual was heard at each Plots 1 and 15. Abundance for this species has been highly variable with a distinct pattern of high numbers one year followed by low numbers the next year.

Northern Leopard Frog was documented at Plot 4, where a single individual was heard. This species has been limited in numbers and distribution throughout the monitoring period (2006-2014).

The 2013 terrestrial and wetland monitoring report (Appendix V) provides detailed information on the ambient air temperature, water temperature, and pH ranges for each of the field visits in 2014.

3.0 Summary of Thresholds

Thresholds have been developed for each component of the Hanlon Creek Business Park Monitoring Program. Each threshold is described within the *HCBP Consolidated Monitoring Program* (NRSI 2010) and is listed in Table 8.

Table 8. Summary of Thresholds by Monitoring Component

Component	Threshold	Exceedance in 2014 (Yes/No, stations)
Groundwater	A specific quantitative threshold is not used. However, groundwater elevations that increase above previously observed seasonal high levels or decline below previously observed seasonal low levels, without an obvious relationship to precipitation, will be identified as observations of concern. Similarly, groundwater quality that differs from previous ranges in parameters, and/or indicates an upward trend, will be identified as observations of concern.	No
Surface Water	1. Any single temperature exceedance of 22°C requires analysis in the annual consolidated monitoring report.	Yes, at HC-A(04), HC-A(06), HC-A(09), HC-A(10), HC-A(12), HC-A(13), HC-A(14), SR-1(01)
	2. Any single temperature exceedance of 24°C triggers the Rapid Assessment and Action Protocol.	Yes, at HC-A(09), HC-A(14), SR-1(01)
Fish	1. A 50% change in the number of taxa represents a potential decline in the suitability of the habitat for Brook Trout. Because coldwater fish communities typically have a lower species diversity, an increase in species diversity may represent a negative change in relation to the Brook Trout management objective. Specifically, the warm-water fish community may increase in species richness as a result of warmer water temperatures, which indicates that the habitat is becoming less suitable for Brook Trout. A decrease in species diversity may also represent a negative change in the suitability of the habitat for Brook Trout, likely attributable to some cause other than water temperature.	No
	2. A 50% reduction in the number of fish captured represents a potential decline in the fish community resulting from habitat impacts. However, it may also represent an improvement in habitat suitability for Brook Trout based on temperature changes.	Yes, at EMS-003 EMS-004

Component	Threshold	Exceedance in 2014 (Yes/No, stations)
Benthic Invertebrates	1. For the Percent Model Affinity (PMA) analysis, the threshold is an “Impact” determination at a station for 2 consecutive years following 2 consecutive years where the determination was “No Impact” at that station.	Yes, at BTH-002, BTH-004
	2. For Total Taxonomic Richness, the threshold is a 50% decline in the total number of taxa at a station, as compared to the results from the previous year.	No
	3. For EPT Taxonomic Richness, the threshold is a 50% decline in the number of EPT taxa at a station, as compared to the average results from the previous 2 years.	Yes, at BTH-001 BTH-003 BTH-005
Vegetation and Soils	1. A change in herbaceous cover by more than 25%.	Yes, at Plot 1, Plot 2, Plot 3, Plot 8
	2. A change in species diversity by more than 25%.	Yes, at Plot 2, Plot 5, Plot 6, Plot 7
	3. A change in canopy cover by more than 25%.	Yes, at Plot 8
Breeding Birds	1. A negative change in species diversity (number of species) by more than 25%.	Yes, at Plot 3, Plot 5, Plot 6, Plot 9
	2. A negative change in the breeding bird abundance (number of individuals birds) by more than 25%.	Yes, at Plot 3, Plot 4, Plot 5, Plot 6, Plot 7, Plot 9
Amphibians	1. A decrease in species diversity (number of species) by more than 2 species.	No
	2. A change in species abundance measured by a decrease in two call codes.	Yes, at Plot 6, Plot 7, Plot 16

4.0 Rapid Assessment and Action Protocol

In 2011 a Rapid Assessment and Action Protocol (RAAP) was implemented as a response protocol for when thresholds are exceeded or when other unexpected environmental issues arise. A six-person committee was set which included a primary and an alternate designated for each represented group (City of Guelph, GRCA, and Monitoring Team). Whenever there was a RAAP event, all six people were contacted via email, and a meeting was scheduled. The list of designated persons for 2014 is shown in Table 9.

Table 9. List of Designated Persons

Affiliation	Name
Monitoring Team (AECOM)	Nicole Weber
Monitoring Team (NRSI)	Andrew Schiedel
City of Guelph	Arun Hindupur
City of Guelph	Adèle Labbé
GRCA	John Palmer
GRCA	(second not identified for 2014)

The specific thresholds that require rapid response are the 22.0°C and 24.0°C stream temperature thresholds, and the turbidity threshold which was initially set at 10 NTU in the Consolidated Monitoring Program guidance document (NRSI 2010). These targets were set with the primary goal of maintaining Brook Trout habitat within the Hanlon Creek tributaries. To determine when temperatures or turbidity exceed these thresholds, a telemetry system was implemented at four stations within the site to monitor temperature, turbidity and depth. This system notified the monitoring staff when there was an exceedance, triggering the RAAP. In addition, any on-site observations of immediate problems, such as sediment observed entering a wetland or watercourse during a rainfall event, one or more of the designated persons should be contacted. If a RAAP is triggered, the basic steps are:

1. After the exceedance/event occurs the monitoring staff member, inspector or notified person will contact the designated persons immediately.
2. The designated persons must meet/conference call within 48 hrs.
3. Notification and corrective actions must be proposed within three business days.
4. Report should be produced.
5. This report should be included in the consolidated monitoring report.

Section 4.1 provides an account of the meetings that occurred as a result of threshold exceedances in 2014.

4.1 Chronology of Events

The following summary is based on the correspondence and meeting minutes of the RAAP committee found in Appendix VI.

An email was circulated to the RAAP group by AECOM on November 3, 2014 identifying an exceedance of 24°C at surface water station HC-A(14). It was determined that the logger was failing, and it was not in fact a temperature exceedance. A redundant temperature data logger was also in place for 2014, and that data was used for 2014 reporting.

5.0 Discussion of Issues

Several issues were identified during the 2014 monitoring season. These were identified based on the exceedances of the various monitoring component thresholds that have been described within the *Hanlon Creek Business Park Consolidated Monitoring Program* (NRSI 2010). Threshold exceedances are identified in Section 3.0. The following is a discussion of the issues that were identified or ongoing in 2014.

5.1 Water Temperature Impacts from Stormwater Management Pond 4

As discussed in Section 2.4.2, water temperatures during summer months of 2014 continued to be elevated as a result of the effects of SWM Pond 4. While surface water temperatures were somewhat lower in 2014 compared to 2012 and 2013, with the weather being normal to somewhat cool compared to other previous years, the influence of SWM Pond 4 continued to be evident in 2014. The evidence is focused on the stations on Tributary A that are the nearest to the SWM Pond 4 outlet. Temperatures did not exceed 22°C or 24°C at those stations, but the thermal effects are evident in the proportion of the summer that the temperature was above 19°C, and by the thermal regime classification in 2014 compared to pre-construction data.

Looking at the temporal evidence, the 2014 thermal regime classifications were warmer than pre-construction years (2009/2010 and earlier) at stations HC-A(04), HC-A(06), HC-A(09) and HC-A(10). In addition, the proportion of time that the temperature was above 19°C at stations HC-A(04) and HC-A(06) was greater in 2014 compared to preconstruction conditions, being 52% and 49% in 2014 versus 9% and 18% in 2010, respectively. In 2009, the summer temperature data demonstrated no time (0%) above 19°C at stations HC-A(04) and HC-A(06). It is clear that SWM Pond 4 has changed the conditions at these stations.

Looking at the spatial evidence, stations HC-A(04) and HC-A(06), located in Tributary A downstream of the SWM Pond 4 outlet, recorded higher average temperatures and little daily fluctuation compared to station HC-A(03) located upstream of the SWM Pond 4 outlet. The subdued daily fluctuation resulted from the very constant temperature of water that continuously discharges from the SWM Pond 4 outlet. Furthermore, the temperatures at the two of these stations that are downstream in Tributary A were consistently in between the upstream temperatures and the SWM Pond 4 outlet temperatures, providing evidence of the mixing of the two sources of flow.

Further downstream at station HC-A(09), it is difficult to discern how much SWM Pond 4 is affecting the temperatures. In 2009, the temperature at this station was at times above 19°C, with a proportion of 2.1% of the 21 days of data that was available that summer. In 2010, station HC-A(09) exceeded 19°C for 34% of the time. This indicates that there has been a history of higher water temperatures at station HC-A(09). The data for 2014 shows that the temperature was above 19°C 42% of the time. This could be a result of the influence of SWM Pond 4, although the greater distance from the pond and the lesser temporal difference in this statistic makes the relationship less certain.

Further downstream in Tributary A, it is unlikely that SWM Pond 4 is affecting the temperatures, as evidenced by the thermal regime classification at station HC-A(11) which was cooler in 2014 compared to pre-construction condition. This cooler thermal regime at station HC-A(11) may reflect the cooling effect of the removal of the online pond in conjunction with building the Hanlon Creek Blvd crossing of Tributary A in 2009. In spite of the cooling in that location, station HC-A(14), which is farthest downstream on the site, was one category warmer in 2014 compared to pre-construction conditions. Therefore, the warmer classification at station HC-A(14) was largely due to factors beyond the potential influence by SWM Pond 4.

As another effect to consider for the stations further downstream of the two stations nearest to SWM Pond 4, stations HC-A(09) and HC-A(14) experienced exceedances of the 24°C threshold. Station HC-A(09) may have been influenced by SWM Pond 4 and, based on review of the groundwater and surface water information, it is unlikely that the warm temperatures at that station were caused by other development-related effects. The exceedances at station HC-A(14) are not unusual, so are less likely to be related to warming from SWM Pond 4. All stations had some time with temperatures over 22°C, but they were nominal amounts of time often rounding down to 0%. It appears that the main issue with stream temperatures in 2014 was the effects of SWM Pond 4, and there is no clear evidence that other aspects of the development are contributing to the exceedances of 22°C and 24°C. Thus, it is appropriate to focus the stream temperature impacts on SWM Pond 4, and assume that any measures to address those impacts will in turn reduce the potential for exceedances of 22°C and 24°C.

Further analysis of the spatial and temporal characteristics of the stream temperatures in Tributary A and Tributary A1 is provided in Section 2.4.2, and a focus on the suitability of the temperatures for Brook Trout is provided in Section 2.4.2.1. Analysis of stormwater management pond temperatures is provided in Section 2.4.2.2, and analysis of the modes of impact of SWM Pond 4 is provided as follows.

Two potential modes of impact by SWM Pond 4 were previously discussed the 2012 and 2013 consolidated monitoring reports. The first mode is the water that is discharging to Tributary A through the SWM Pond 4 outlet; the second is the pond's effects on adjacent groundwater that eventually discharges to Tributary A as groundwater. They are outlined again as follows.

5.1.1 Warm Water Discharging Through SWM Pond 4 Outlet

In 2014, the continuous outflows from the SWM Pond 4 cooling trench continued to be approximately 3 to 6°C warmer than the upstream water temperatures at station HC-A(03) in Tributary A. The resulting temperature in Tributary A immediately downstream at station HC-A(04) is closer to the SWM Pond 4 outflow temperatures.

As discussed in Section 2.4.2.2, the cooling trench at SWM Pond 4 has limited performance during storm events. It lowers the pond outflow temperatures in between storm events, but only mitigates temperatures for a few hours after a storm event begins. Thereafter, the temperature is largely driven by the pond outflow temperature. This is understood to be a potential limitation of cooling trenches, with the understanding that the first flush of water has the greatest potential for thermal impact. Nevertheless, it is important to understand that the cooling trench may be functioning to mix groundwater with the outflow from SWM Pond 4, and its perceived performance under current conditions may not reflect extensive absorption of heat by the rock or groundwater in the cooling trench. If the continuous discharge from the SWM Pond 4 outlet were not occurring, there may be additional heat capacity in the rock and surrounding groundwater to facilitate additional cooling of the first flush of a storm event. Refer to

Section 2.4.2.2 for further explanation of the current function of the cooling trench at SWM Pond 4.

In order to improve the performance of the cooling trench and mitigate the effects of the continuous discharge from the pond, herbaceous species and vines were planted along the cooling trench in the fall of 2012. These were installed as an additional mitigation feature with the hope that they would grow over the rock lined cooling trench and reduce the impacts from solar radiation. It was determined that they provided little benefit during their first year as they covered only a small area of the trench, and these benefits continued to be limited in 2014. It may be necessary to augment these plantings, or to pursue additional measures. It is recommended that further measures be developed and implemented in order to address the warming from the continuous discharge.

5.1.2 Warming of Groundwater Adjacent to SWM Pond 4

The warming of the groundwater adjacent to, and down-gradient from, SWM Pond 4 continued in 2014. In 2012 it was determined that surface water from SWM Pond 4 could be migrating toward Tributary A through the ground as another pathway from SWM Pond 4 to Tributary A. This was evidenced by elevated groundwater temperatures compared to pre-2012 monitoring and compared to groundwater temperatures up-gradient from SWM Pond 4 in the same year. This effect continued in 2013 and is again evident in 2014.

In July and August, 2014, the water temperatures at monitoring well MW119A, located down-gradient from SWM Pond 4, were 4 to 5°C higher than those at monitoring well MW 131, located up-gradient of SWM Pond 4. This is a clear indication that an effect is occurring, and it is clearly illustrated on Graph G24a in Appendix G of the groundwater monitoring report (see Appendix II of this report). In addition, groundwater temperatures at monitoring well MW119A and piezometers PZ-13D and PZ-14D demonstrated potentially-elevated temperatures (Section 2.4.1).

Mitigation of this mode of effect would need to either lower the temperature of the water in SWM Pond 4, or curtail the flow of groundwater through the pond. It is recommended that such measures be developed and implemented.

5.2 Change in Benthic Invertebrate Community at Five Stations

5.2.1 Sequential PMA-Analysis 'Impact' Determinations at Two Stations

Two stations, BTH-002 and BTH-004, produced an exceedance of the first benthic invertebrate threshold in 2014. Station BTH-004 had previously experienced this threshold exceedance in 2013 resulting from two consecutive years of 'impact' following two years of 'no impact'. In 2014, an 'impact' determination was made at BTH-004 for the third consecutive year.

Station BTH-002 had an 'impact' determination for the fourth consecutive year. These stations are in sequence downstream of the confluence of Tributary A and Tributary A1. The occurrence of 'impact' determinations at both of these stations suggests a change in the quality of the benthic community at these stations. The cause of these determinations is not clear at this point in time, although it is understood that BTH-002 is analyzed using a different model community. The community used is for streams with rock/cobble substrate, and it sets a higher standard for BTH-002. Monitoring using the PMA analysis should continue with the intention of determining whether or not a 'no impact' determination is observed again at these stations.

5.2.2 Change in EPT Richness by 50% at Three Stations

Three stations, stations BTH-001, BTH-003, and BTH-005, exceeded the third benthic invertebrate threshold in 2014. When compared to the averaged EPT richness results from 2012 and 2013, BTH-001 experienced a reduction in EPT Richness of 62.7%, BTH-003 experienced a reduction of 81.5%, and BTH-005 experienced a reduction of 89.3%, all of which exceeded the threshold of a 50.0% decrease in EPT richness from the average of the previous two years. EPT richness also decreased at BTH-002 and BTH-004 but not enough to result in an exceedance.

There appears to be a trend of decreasing EPT richness across the five benthic monitoring stations since 2008 and 2009 when EPT richness was highest. Stations BTH-001, BTH-002, and BTH-003 have been monitored the longest, and they show lower EPT richness in 2006 and 2007, with the exception of BTH-002 in 2006. More recent results are lower than the EPT richness in 2006 and 2007, beginning with declines at those stations in 2011 and 2012. The year 2013 showed some recovery of the EPT richness at three of five stations. It is important to note that the change in level of identification that affected the overall taxonomic richness in 2013 did not apply to the EPT richness, because Ephemeroptera, Plecoptera and Trichoptera groups were identified to the same taxonomic resolution as the data prior to 2013.

Possible reasons for the decreasing trend in EPT richness include the drought conditions in 2012, and the continuous discharge from SWM Pond 4 beginning in late 2011. In 2012, EPT richness declined substantially at all stations except BTH-005. It is possible that the continuous discharge from SWM Pond 4, which affected the benthic sampling results for the first time in 2012, helped to maintain flows at the nearby BTH-005 during the drought conditions. However, the influence of the continuous discharge may not have been as pronounced at the other stations, and the decline in EPT richness may therefore be attributed to the drought. The monitoring report for 2012 confirms this for BTH-002, BTH-003 and BTH-004. However, it was not understood why BTH-001 had a decline in EPT richness, because it is not far downstream of BTH-005 and received similar flow augmentation from SWM Pond 5.

It is not clear why this trend has continued in 2014. Since 2012, the stations with low EPT richness have experienced similar levels or further decline. Station BTH-005 has also now declined. The continuous discharge from SWM Pond 4 continues, which has a positive effect of augmenting baseflow but also causes increases in water temperatures during the summer, with its influence extending downstream through BTH-005 and BTH-001 and to some extent BTH-002. Baseflows were good in 2014 compared to previous years, but were notably lower in 2012. The drought year of 2012 also affected water temperature. Clearly SWM Pond 4 is not the only factor, highlighted by the fact that station BTH-003 exhibits declining EPT richness very clearly, even though it is on Tributary A1, which can be considered independent of the effects of SWM Pond 4.

5.3 Reduction in the Number of Fish Captured by 50% at Two Stations

For the second fish threshold, two stations, EMS-003 and EMS-004, exhibited a 50% reduction in the number of fish captured. At EMS-003 this occurred due to the decrease in total catch from 28 fish in 2013 to 10 fish in 2014, a 64% decline in fish capture. At

EMS-004 the total catch decreased from 197 in 2013 to 51 in 2014, the equivalent of a 74% decrease.

The catch totals at EMS-003 have been consistently low since monitoring began in 2006. As a result it has a greater likelihood of exhibiting threshold exceedances than the other 4 monitoring stations since a small fluctuation in fish presence within the delineated site could result in a 50% decline. This monitoring station is located on a small groundwater-fed tributary (Tributary A1) to Hanlon Creek Tributary A, which typically provides less habitat than Tributary A. Numbers of fish have been low in the past, being similar in 2007, and lower in 2010 and 2012. Those years registered as threshold exceedances as well, but as noted the low numbers of fish predispose this site to an exceedance. Therefore, the results are considered typical for station EMS-003.

At station EMS-004, an unusually high number of fish were captured in 2013. The 74% decrease in the number of fish captured reflects a return to the numbers captured prior to 2013.

5.4 Changes in Vegetation

5.4.1 Change in Herbaceous Cover by 25% at Four Stations

Herbaceous cover exceeded the threshold positively in Plots 2 and 8 which is seen as a positive trend for these plots. Plots 1 and 3 both exceeded the lower reach of the threshold in 2014.

In Plot 1, the presence of shallow water within the plot during the July vegetation monitoring date reduced the amount of herbaceous cover from recent years. This exceedance is not seen as a negative impact overall as the vegetation community is adapted to hydric soils and standing water provides a number of benefits to wildlife including anurans, mammals and birds. The western fringe of Plot 1 accounts for most of the herbaceous vegetation within the plot as it is a transition between meadow and the willow thicket swamp. Within the swamp itself most herbaceous vegetation is found growing on the hummocks of willow clumps or aquatic species such as Lesser Duckweed (*Lemna minor*).

While increases in herbaceous species in Plot 3 (7.2% between 2013 and 2014) reflect a positive change in recent years, the 16.3% cover in 2014 is still well below the pre-construction average of 57.83%. Should the site receive abundant precipitation during the spring of 2015, vegetation monitoring may find that herbaceous cover continues to build on the 2014 figures. It should also be considered that the mortality of Ostrich Fern (*Matteuccia struthiopteris*) during the driest monitoring years would require time for the population to rebound (assuming conditions are suitable for the species) to pre-construction numbers.

5.4.2 Change in Herbaceous Species Diversity by 25% at Four Stations

Species diversity positively exceeded the pre-construction threshold in both Plots 2 and 6. Given that these increases were not based on the addition of aggressive non-native species to the plots, these changes are considered positive. Plots 5 and 7 both fell below the threshold in 2014. With consistently low species diversity, the threshold for Plot 5 is based on a small number of species and is thus easily exceeded. Had the 8 species observed in 2014 monitoring been raised to 10, the plot would have been within the lower reach of the threshold. As a dense conifer stand, it is not anticipated that species diversity will change drastically within this plot in the near future.

Plot 7 was just below the lower reach of the threshold in 2014 but still remains one of the most diverse plots within the subject property. Some discrepancy has been attributed to the potential shifting of the monitoring plot; the hummocky terrain means that a shift of several degrees in either direction for the five 1m x 1m sub-plots can include or exclude several species from the plot list. Changes in groundwater levels may be responsible for the disappearance of wetland species such as Marsh Skullcap (*Scutellaria galericulata*), Clearweed (*Pilea pumila*) and Spotted Jewelweed (*Impatiens capensis*), none of which were ever widespread or abundant within the plot. Groundwater elevations at Piezometer 7D have been monitored with a continuous data logger since November 2007. Levels at Piezometer 7D appear to have been approximately 5cm higher in the years 2008 and 2009 compared to the years 2010 to 2014, with a notable low in the summer of 2012. This slight change in groundwater elevation is another potential explanation of the absence of these wetland species. Ongoing monitoring will continue to assess the increase or decrease in species diversity.

5.4.3 Change in Canopy Cover by 25% at One Station

Plot 8 remains the only plot which exceeded the canopy cover threshold. As reported in the 2011 HCBP Consolidated Monitoring Report (NRSI 2012a), canopy cover has been reduced in Plot 8, but the area of impact, adjacent to the plot has been restored through native plantings according to the HCBP EIR Restoration Plans. These plantings are being monitored for success and will increase shading to Tributary A that bisects Plot 8 as they mature.

5.4.4 Decreasing Coefficient of Wetness at Two Stations

Although Coefficient of Wetness (CW) is not used as a specific threshold for the vegetation monitoring, it is noteworthy that the CW values have shown a drying trend between 2011 and 2014 at Plots 16 and 18. These plots are located in close proximity to recent development (Block 9 and Block 10) and Hanlon Creek Boulevard. Groundwater levels at adjacent monitoring wells have been analyzed for temporal patterns and compared to the ground elevations (Section 2.7.1.1). However, the drought year in 2012 is the only obvious groundwater effect. Furthermore, it appears that fluctuations in groundwater levels would have little to no effect on the soil wetness in the wetlands because their elevations have never been above the ground surface of the wetlands. Groundwater levels in the vicinity of Plots 16 and 18 do not show a trend that matches the declining trend in CW values. Monitoring of vegetation and groundwater should continue at these plots in order to determine whether there is a relationship between groundwater and the CW values. In addition the presence and depth of surface water should be monitored in some manner each spring.

5.5 Change in Breeding Bird Species Diversity by 25% at Four Stations

Breeding bird species diversity was below the threshold at four plots in 2014 with the remaining plots within the threshold. No plots positively exceeded the threshold in 2014. Data indicates that species diversity in 2013, and 2012, to some extent, were exceptionally high in comparison to previous years which raised the 25% threshold notably. In 2014, Plots 3, 6 and 9 were near the lower reach of the threshold, while Plot 5 was well below the threshold.

Plot 6 was near the construction at Block 14. If there was an effect from construction activity, it is expected to have been temporary. It is noted that Plots 3, 5 and 9 are located in areas that are well-removed from active construction and it is inferred that trends in these plots are the result of natural fluctuations. Breeding bird survey dates have remained essentially the same over the monitoring period as well as the habitats within these plots. Reductions in the extent of agricultural land use in Phase 3 have resulted in fallow fields in the vicinity of Plot 3 and 9 which should increase species diversity. Plot 5 is situated within an area of low vegetation diversity with a uniform canopy and minimal understory, shrub layer or herbaceous layer. Given the simplicity of the habitat, this area is not likely to support a diversity of bird species.

Overall, the 2014 data strongly reflects a year of lower-than-average bird diversity. Temporary impacts relating to nearby development, as well as annual fluctuations in bird presence at each plot are to be expected. Continued monitoring will help to inform long-term trends.

5.6 Change in Breeding Bird Abundance by 25% at Six Stations

Plots 3, 4, 5, 6, 7 and 9 were all below the 25% threshold in 2014. Reflective of the reduction in species diversity in 2014, breeding bird abundance was also notably lower than average for a number of plots in 2014. As mentioned in previous monitoring reports, observations of flocks can have a notable impact on bird abundance figures. The threshold set within Plots 6 and 9 for pre-construction (2006-2009) both include very large numbers of Red-winged Blackbird or Canada Geese which inflated the threshold substantially. In 2014, no more than 8 individuals of a species were observed at a given plot (many tallies were 6 or lower). As species diversity was lower in 2014, it is expected that abundance would be lower. As both 2012 and 2013 constitute years of high bird abundance, and the presence of flocks within pre-construction threshold calculations, 2014 data is generally on average with the during-construction data set despite the 6 threshold exceedances which were documented.

Monitoring should continue to assess breeding bird abundance to determine if bird abundance is being maintained across the site and within the different vegetation communities.

5.7 Decline in Amphibian Species Abundance at Three Stations

A decrease in two calling codes was established as the threshold in the HCBP Consolidated Monitoring Program (NRSI 2010). Several of these decreases were observed in 2014 including:

- Gray Tree Frog in Plots 7 and 16 – no individuals recorded in 2014, down from a call code 2 recorded at each of these plots in 2013,
- Spring Peeper in Plot 6 – no individuals recorded in 2014, down from call code 2 recorded in 2013,
- Wood Frog in Plots 6 and 16 – no individuals recorded in 2014, down from a full chorus of 3 in each plot in 2013,

It should be noted that the overall abundance of both Gray Tree Frog and Spring Peeper across the site reflects data gathered in 2013 and abundance for both has remained relatively consistent since 2006. As noted in previous monitoring reports, the use of SWM ponds by Spring Peepers, as well as American Toads, has increased notably since their creation. The continued establishment of riparian and aquatic vegetation within SWM ponds will likely continue to provide suitable foraging and breeding habitat for some anuran species.

Seemingly subject to alternating years of high abundance followed by low abundance, Wood Frog numbers were low in 2014, similar to data collected in 2012, 2010, 2008 and 2006. Research shows that prolonged periods of dry weather may reduce adult breeding populations either directly or through reduced juvenile recruitment and a shortened larval period (Berven 1990).

The remaining identified species, Green Frog, Northern Leopard Frog, Pickerel Frog and Western Chorus Frog have all been observed intermittently within the subject property dating back to the 2007 monitoring year. Generally these species have been observed in low numbers at a call code of 1 or 2. It is likely that these species have always existed in low numbers within the property and are subject to natural population fluctuations.

Two of the species abundance decreases which surpassed the threshold occurred in Plot 16. Previous monitoring reports have noted the drier conditions being observed at the plot in recent years. During 2014 calling anuran surveys, water was present throughout April and May but had dried up by June. All three survey dates note calling anurans from the adjacent stormwater conveyance swales including approximately 30 Gray Tree Frog, Spring Peeper and American Toad during the May 21 survey. While calling anurans have decreased within the Silver Maple swamp where Plot 16 is located, the vegetated ditches to the west of the plot have become particularly valuable to breeding anurans.

It is difficult to determine the cause of the observed changes at Plot 16. There is not a clear correlation with the nearby development in Block 9 and 10, or the observed groundwater levels at MW103. The reduction in seasonal standing water within the central portion of the swamp has undoubtedly made the Plot less suitable for anuran breeding. It could be that this change is largely related to fluctuations in rainfall from one year to the next. It is also possible that the new road, stormwater conveyance trenches and the development of the adjacent blocks are altering the hydrology sufficiently to reduce the seasonal standing water in the swamp. The swamp and surrounding lands should be investigated in the spring to determine whether there are substantial changes in hydrology.

6.0 Summary of Corrective Measures Undertaken

No corrective measures were undertaken in 2014. The RAAP group met on one occasion regarding a temperature exceedance that resulted from a faulty data logger.

The temperature effects continued at SWM Pond 4, and the corrective measures undertaken in 2012 were again monitored for effectiveness in 2014. The corrective measures undertaken in 2012 included:

1) raising the outlet of the cooling trench at Pond 4 (this was removed in early 2013),
2) raising the weir level at the pond outlet at Pond 4, and
3) planting of aquatic vegetation throughout the shallow areas of the pond as well as planting vines and herbaceous species in and around the cooling trench at Pond 4.

The decision to wait on implementing additional corrective measures was based on the fact that the vegetation planted in 2012 can take several years (5+) to become well established and mature in order to function as intended. Looking ahead, it may be necessary to undertake additional corrective measures to address the thermal impacts from SWM Pond 4.

While other issues have been identified through review of the monitoring results, there were no other clear cause-and-effect relationships that constituted problems to be rectified through corrective measures.

7.0 Recommendations

7.1 Actions for 2014

Based on the 2014 monitoring results, it is recommended that additional corrective measures be developed to address the effects of SWM Pond 4 on water temperatures in Tributary A. This may be an extension of vegetation-planting measures already taken, or new measures. The need for additional monitoring requirements should be considered in conjunction with the development and implementation of the corrective measures.

While other issues were identified as a result of threshold exceedances or other occurrences, none of the issues were clearly linked to impacts from development. Therefore, no further actions are recommended at this time based on the available monitoring information.

7.2 Future Monitoring

2014 marked the fifth year of construction-phase monitoring at the HCBP. The following recommendations for monitoring are made with this in mind.

It is recommended that monitoring continue with diligent attention given to stream temperatures and the SWM Pond 4 mitigation measures put in place to date, using the RAAP as prompted by any stream temperature or turbidity exceedances. This will ensure that attention is given to any ongoing patterns in stream temperature, and actions can be taken if deemed necessary. Additional monitoring may also be required to inform the development and implementation of measures to mitigate the effects on stream temperatures.

The long-term groundwater monitoring program at the HCBP site should continue in 2015 on a quarterly basis as previously recommended. Particular attention should be given to monitoring wells MW119A, PZ-13D and PZ-14D regarding the temperature effects of SWM Pond 4, and to monitoring wells MW103 and MW118A regarding the declining CW values at vegetation Plots 16 and 18. As a new monitoring item, surface water should be monitored at Plots 16 and 18 and adjacent roads, swales and development blocks in order to determine whether surface hydrology has been altered in a manner that is affecting Plots 16 and 18. Groundwater samples should continue to be collected from selected monitoring wells and analyzed for the established water quality parameters. The improved filtering of water samples should be continued as standard practise.

The surface water monitoring program during and post construction should continue in 2015 as per the Standard Operating Procedures for the Consolidated Monitoring Program (NRSI 2010) to ensure temperature targets are met and water temperatures are suitable for Brook Trout. Monitoring of stormwater management ponds should also continue in 2015 to monitor their effectiveness, including the bottom draw outlet and cooling trench performance. Flow monitoring should be resumed at stations HC-A(08) and HC-A(09) in order to improve analysis of the fish and benthic invertebrate monitoring results.

Fish and benthic invertebrate monitoring should continue to occur in 2015 as per the Standard Operating Procedures for the Consolidated Monitoring Program (NRSI 2010).

Vegetation monitoring should continue as per the Standard Operating Procedures for the Consolidated Monitoring Program (NRSI 2010), with the following notes for 2015. Special attention should be given to Plots 16 and 18 to determine if there is a continued decline in CW values. The frequency of terrestrial monitoring should be reviewed to determine if some or all of the plots should be monitored at a reduced frequency.

Monitoring of the aquatic and riparian vegetation within the SWM Pond 4 and herbaceous plants along the cooling trench should also continue in order to monitor the survival and establishment of the vegetation planted in the fall of 2012.

Breeding bird and amphibian monitoring should continue in 2015 as per the Standard Operating Procedures for the Consolidated Monitoring Program (NRSI 2010).

Monitoring of all anuran plots should continue with a particular focus on changes observed within Plot 16. In the case that anuran diversity and abundance is found to be impacted by development activities, management recommendations may be made in order to mitigate or reverse negative trends.

8.0 Conclusions

Monitoring at the Hanlon Creek Business Park in 2014 was successful in providing useful information to describe environmental conditions on site, detect issues and develop solutions. Elevated stream temperatures and the contributing temperature impacts from SWM Pond 4 continued to be the most prominent issue in 2014. As such, monitoring in 2015 should give particular attention to this issue through the continued monitoring of nearby wells and the effectiveness of the planted vines and aquatic vegetation. The RAAP group should carefully review any stream temperature threshold exceedances. Additional corrective measures should also be developed to mitigate the effects on stream temperatures, including additional monitoring as required to inform such measures.

The decline in CW at vegetation Plots 16 and 18 represents another issue to be investigated further, and surface water monitoring at these plots should be implemented.

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MAPS

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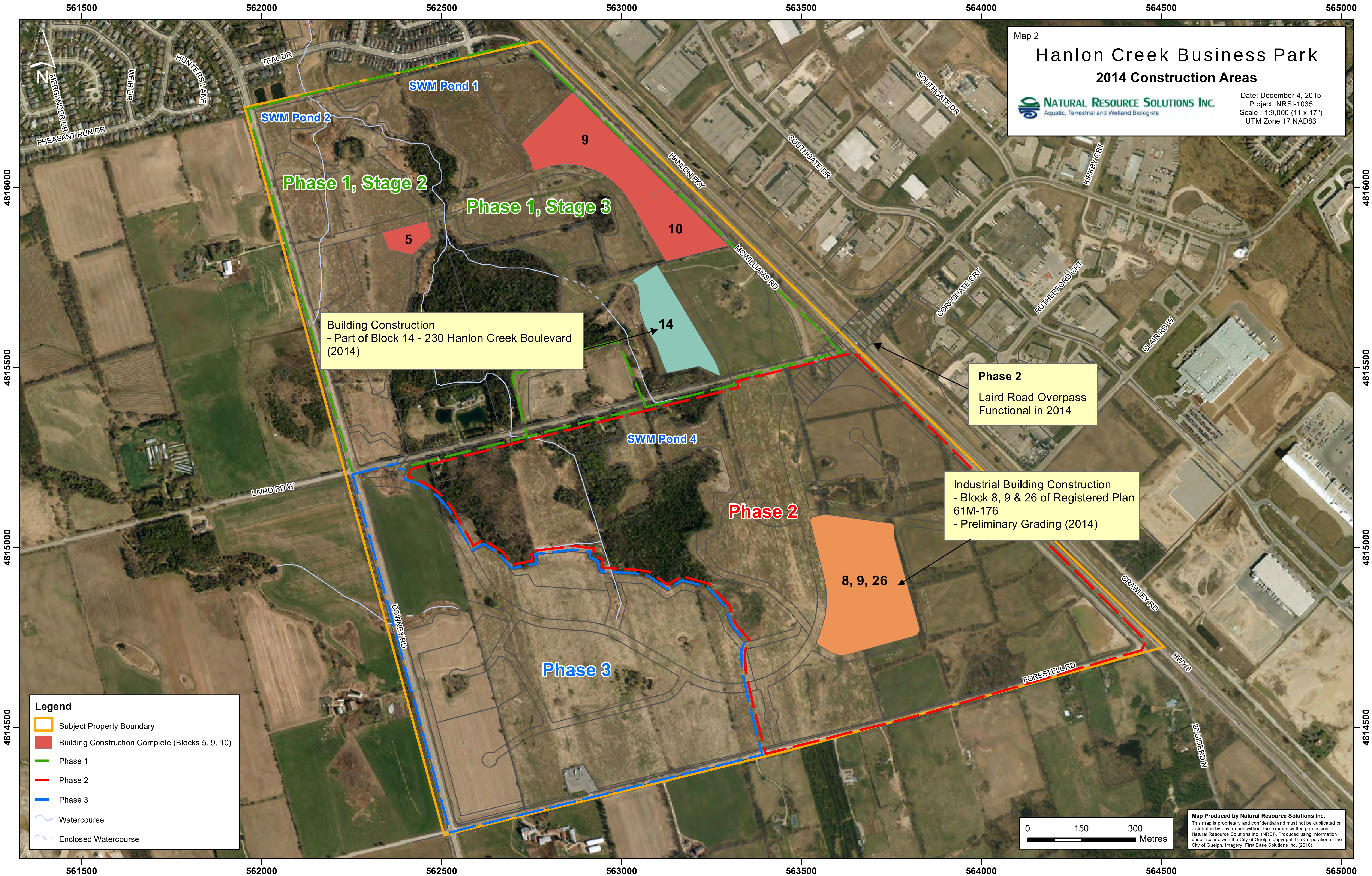

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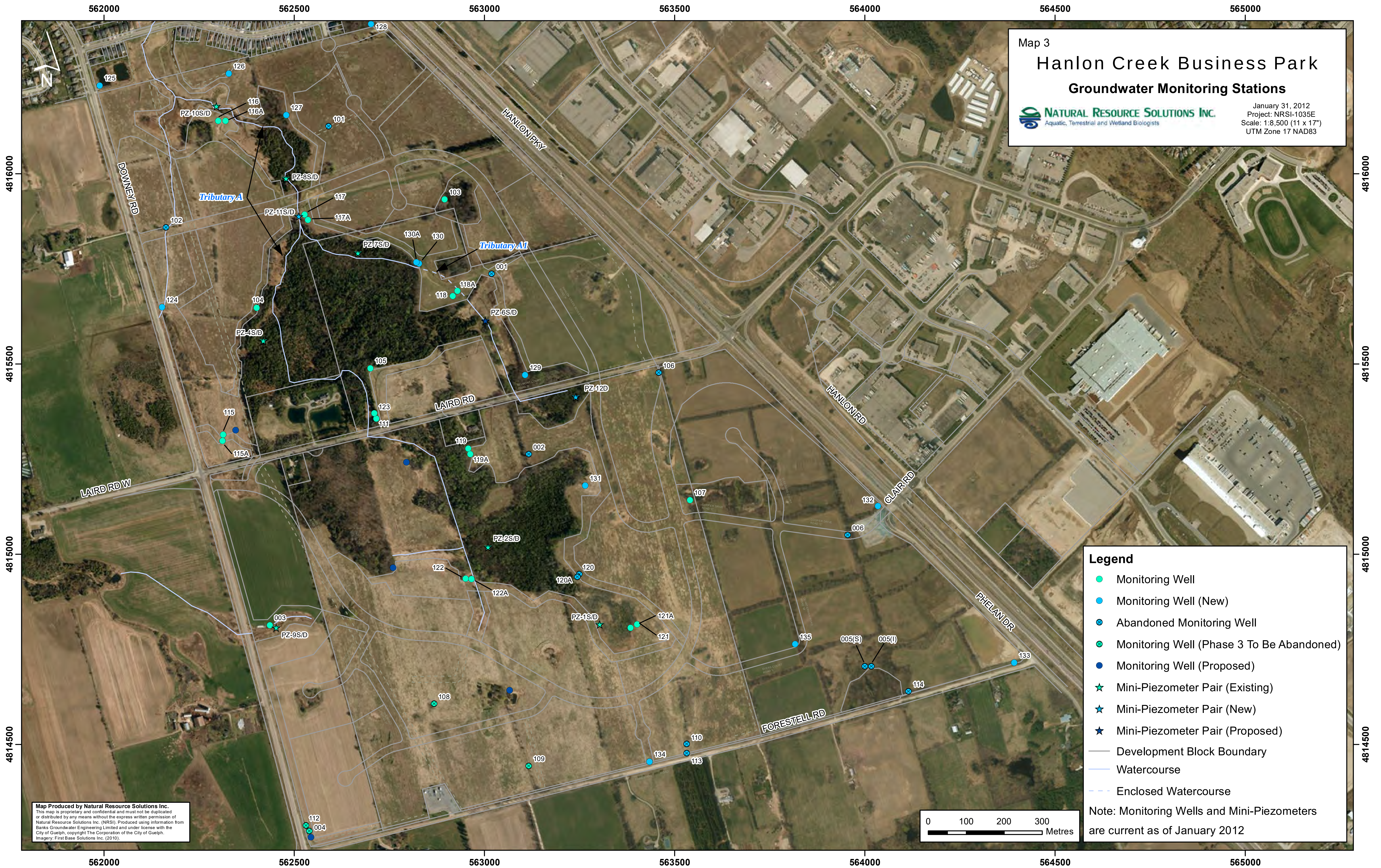

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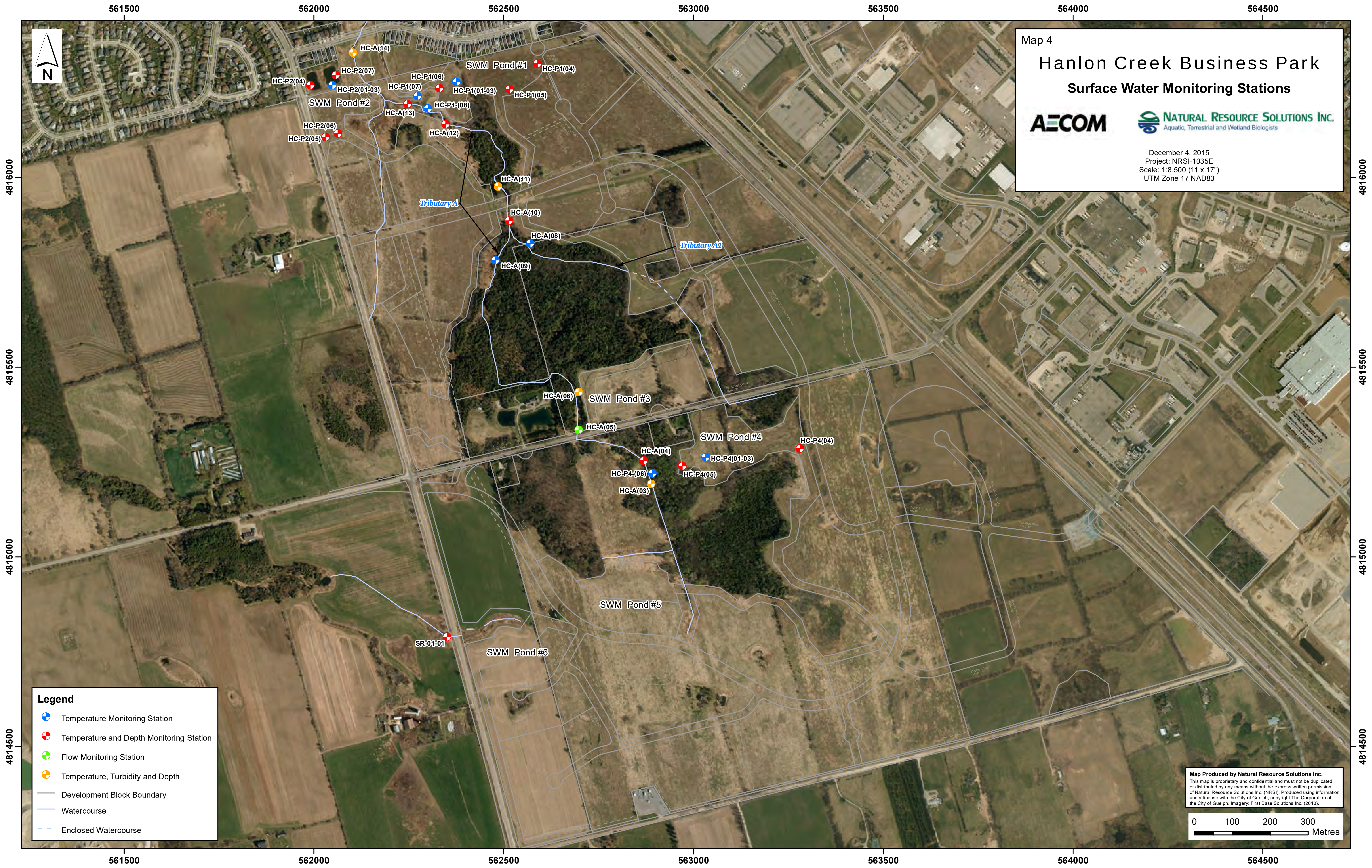

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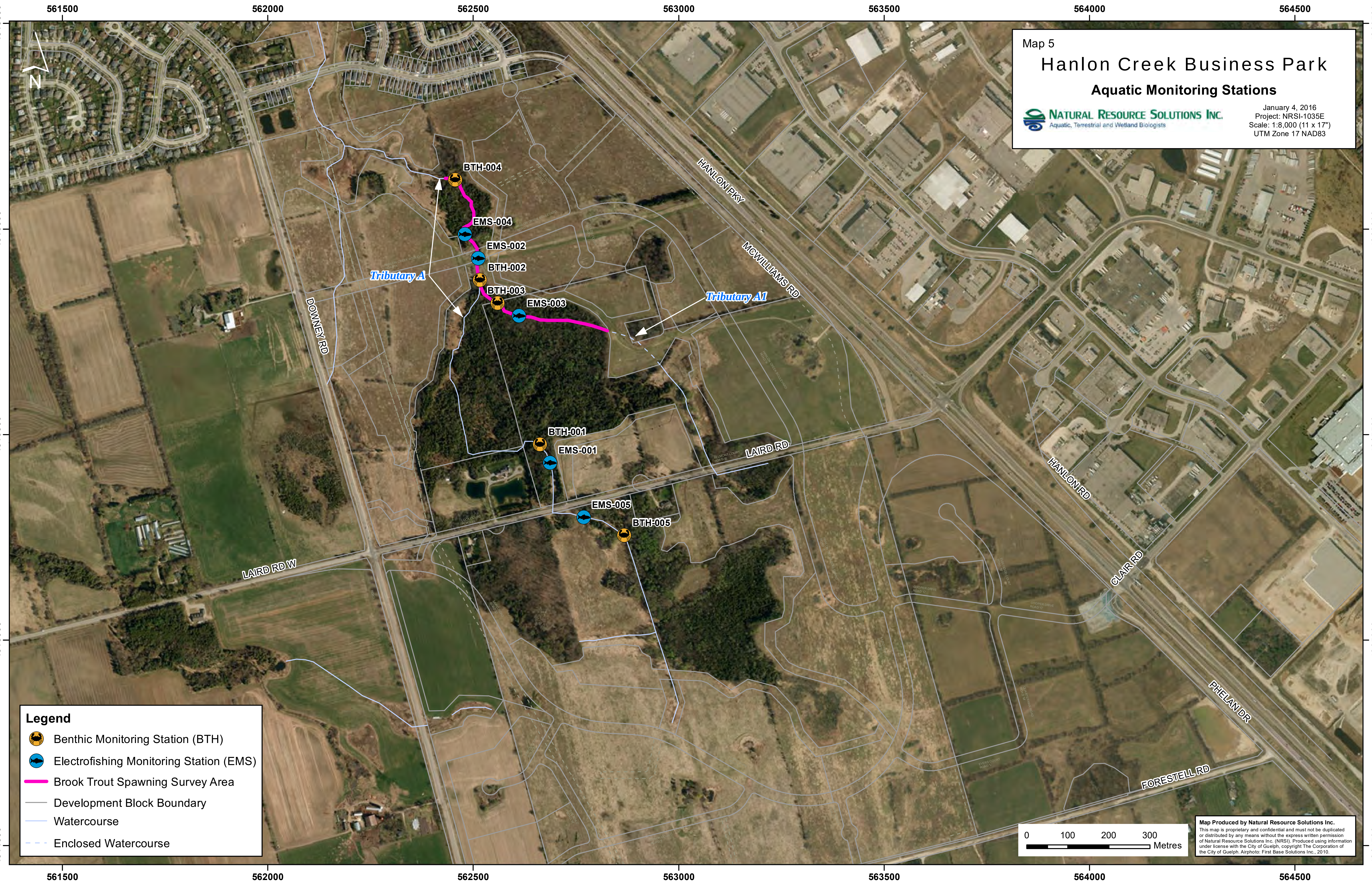

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APPENDIX I

CONSTRUCTION INSPECTION REPORTS

APPENDIX II

GROUNDWATER MONITORING REPORT

APPENDIX III

SURFACE WATER MONITORING REPORT

APPENDIX IV

AQUATIC MONITORING REPORT

APPENDIX V

TERRESTRIAL AND WETLAND MONITORING REPORT

APPENDIX VI

RAPID ASSESSMENT AND ACTION PROTOCOL DOCUMENTATION

Environmental Inspection Report

Project Number:	1041
Construction Project:	HCBP Phase 2
Date of Inspection:	April 10, 2014
Location:	Hanlon Creek Business Park – Phase 2
Works inspected:	Stability and condition of areas adjacent to natural features after winter and spring melt.
Activity:	No on-site activity
Weather Conditions at time of Inspection:	14^{o}C, sunny, windy, no precipitation
Weather Conditions 24 hrs prior to Inspection:	11^{o}C, sunny, windy, no precipitation

Comments:
An inspection was conducted to review the overall condition of the site following winter conditions and spring thaws.

As noted in inspection report from April 2013, some trees within the open space blocks have failed and are laying across the pedestrian/access trails. It is recommended that the tree limbs be cut back so as not to impede the access trail. Excess woody debris can be placed back into the open space area to provide habitat for wildlife or taken off-site. The downed limbs are located around SWM Pond 4 (Photo 1) and along east side of Open Space Block 12.

The herbaceous vegetation (although not entirely comprised of the native seed mix as recommended) is well established throughout the site, with no evidence of wash-outs or material migration into the open space blocks.

Water flows from the SWM Pond 4 cooling trench were quite high during the inspection conducted on April 10; however, water continues to flow clear of sediment. The coir log that was placed at the west end of the cooling trench as a temporary sediment control measure (during construction) has fallen into the tributary and is resting on the bottom. Water flows have also begun to create a channel through the rocks that were placed between the outfall and tributary. As a result, the high water velocities are leading to undermining on the adjacent bank (Photos 2 and 3). It is recommended that the RAAP team discuss next steps with the SWM Pond to ensure that the adjacent bank does not continue to be undermined and tributary temperatures are not impacted.

As identified in the April 2013 inspection report, although not directly impacting the natural areas, it was noted that a small section of the pedestrian/access trail has washed-out in the area adjacent to the southeast corner of Open Space Block 12. The wash-out is running into the stormwater channel.

The April 2013 inspection report also identified a number of areas between the east side of Open Space Block 12 and the pedestrian/access trail with exposed soils or areas covered in trail surfacing material (limestone screenings) with no topsoil. Where topsoil is present, the vegetation is not establishing well, therefore, it is recommended that these areas be treated with topsoil and seeded in the spring to ensure stabilization of the slope.

The north and east slopes surrounding the isolated PSW remained stable over the winter, with no evidence of slumping (Photo 4). The heavy-duty silt fence is still in place and functioning well. It is recommended that this area continue to be monitored throughout the spring to ensure that the vegetation remains stable during spring rains. The removal of the heavy-duty silt fence can be considered at that time.

It appears that the MTO contract for the Laird Road overpass resulted in the removal of the heavy-duty silt fence along the west side of the isolated PSW (Photo 5). A majority of the wetland area is higher in elevation to the adjacent ditch; however, as vegetation is still not fully established, it is recommended that this area continue to be monitoring to ensure that no material migrates into the PSW.

Follow-up Requirements:

- Cut back trees that have fallen onto pedestrian trail,
- Treat slope between east side of Open Space Block 12 and pedestrian trail with topsoil and seed in spring to stabilize,
- Discuss options for SWM Pond 4 and water levels with Hanlon RAAP team,
- NRSI to conduct follow-up inspections to monitor flows within cooling trench and ensure recommended measures have been undertaken

Is Work in Compliance:	**Yes**	**No**
Is This the Final Inspection:	**Yes**	**No**

Inspection Report Distribution List

Title	**Name**
City of Guelph - Environmental Planner	Adèle Labbé
City of Guelph – Supervisor of Technical Services	Grant Ferguson
Cooper Construction – Director of Development	Bill Luffman
Husson Limited	Paul Husson
Husson Limited	Carmen Sframeli
Husson Limited	Jay Dharmadurai
TACC Construction Ltd.	Chris Bruno

Prepared By: Tara Brenton **Date: April 21, 2013**

Photo 1: Example of trees that have failed and are laying on pedestrian trail

Photo 2: Water flows within SWM Pond 4 cooling trench

Photo 3: Water flows within SWM Pond 4 cooling trench, coir log and bank undermining

Photo 4: Vegetation establishment along north side of isolated PSW


Photo 5: Existing conditions along west side of isolated PSW adjacent to MTO road work

Environmental Inspection Report

Project Number:	1041C
Construction Project:	Cooper Drive Construction Monitoring
Date of Inspection:	November 14, 2014
Location:	Hanlon Creek Business Park – Phase 2
Works inspected:	Erosion and sediment controls along natural feature north of Cooper Drive.
Activity:	Grading occurring on lot south of Cooper Drive
Weather Conditions at time of Inspection:	1.0^{o}C, mostly cloudy, low wind, light snow
Weather Conditions 24 hrs prior to Inspection:	1.0^{o}C, cloudy, windy, light snow

Comments:
An inspection was conducted to review the overall condition of the sediment and erosion controls related to the construction activities on the lot south of Cooper Drive and north of Cooper Dr. along the natural feature.

Construction activities occurring south of Cooper Dr. consisted of earth moving and grading with the majority of activity taking place adjacent to Laird Road. Heavy duty sediment fencing was in place around the perimeter of the site and appeared to be in good condition and functioning as required (Photo 1). No concerns were noted relating to the activities on the lot.

Photo 1. Construction activity along Laird Road, south of Cooper Drive (facing W)

To the north of Cooper Dr. heavy duty sediment fence was installed at the toe of the slope and around the perimeter of the existing natural feature (Photos 2 and 3). This fence was observed to be in good condition and appeared to be functioning as intended. No construction activities were occurring in the immediate vicinity of the feature at the time of the inspection.

Photo 2. Existing sediment fence along the south edge of the isolated wetland north of Cooper Drive (facing W)

Photo 3. Existing sediment fence along the south edge of the isolated wetland north of Cooper Drive (facing E)

Follow-up Requirements:

- Additional site visit once grading works are complete to ensure construction activity has been maintained within the fenced off area

Is Work in Compliance:	**Yes**	**No**
Is This the Final Inspection:	**Yes**	**No**

Inspection Report Distribution List

Title	**Name**
Cooper Construction – Director of Development	Bill Luffman

Prepared By: Steve Burgin **Date: November 26, 2014**

NATURAL RESOURCE SOLUTIONS INC.
Aquatic, Terrestrial and Wetland Biologists

Memo

Project No. 0980A

To: **Grant Ferguson (City of Guelph)**

From: **Pat Deacon (NRSI)**

CC: **Tara Brenton (NRSI)**

Date: **November 19, 2014**

Re: **HCBP Phase 1**
White Cedar Hedgerow Replacement Stock - Inspection Summary

The following provides a summary of the tree stock replacement in Phase 1, Stage 3 of the Hanlon Creek Business Park (HCBP) on November 10, 2014. A total of 12 potted eastern white cedar (*Thuja occidentalis*) were planted along the rear of residential lots fronting onto Teal Drive. These trees were planted to replace the dead or declining stock which was previously identified by NRSI during the 2 year warranty inspection.

Bomar Landscaping Inc. was on site to install the plantings on November 10, 2014. NRSI biologist, Pat Deacon, conducted a site visit and noted the following:

- 12 eastern white cedar of approximately 2.5m in height were planted along the rear of residential lots fronting onto Teal Drive, predominantly at the eastern extent of the cedar hedgerow. See Photo 1,
- All trees were in excellent health and were planted to a correct depth and in-filled using native topsoil as per original specification drawings provided in the planting plan,
- Several trees immediately west of the chain link gate were installed at the crest of the slope and thus in-filled soil on the downslope of the stem is limited but acceptable. These trees will be inspected by NRSI in 2015 as part of ongoing construction monitoring to ensure that they have rooted securely and were not subject to erosion which would compromise the survival of the trees.,
- The site was free of garbage and debris upon inspection,
- Trees were not staked upon inspection,
- Trees had not been wrapped in burlap upon inspection,
- At the rear of several lots, stands of staghorn sumac (*Rhus hirta*) at the western end of the hedgerow, part of the visual barrier, have been cut-off at the ground. Established white cedars are still present and it is expected that the sumac will sucker back in time and pose no risk to the survival of the cedars. See Photo 2.

The Standard Notes in the tender documents note that;

- *"For plantings in open areas (i.e. SWM ponds, berms) provide adequate protection against winter damage. Coniferous trees to be wrapped with burlap from winter freeze-up to spring thaw during the warranty period,*
- *All deciduous caliper trees and container or balled and burlapped (B&B) coniferous trees are to be double staked with 50x50mm timber stakes and rubber tree ties."*

Due to the size of stock planted on November 10, 2014, it may not be necessary to double stake; however, it is recommended that Bomar consider wrapping the plant material to ensure that it survives through the winter.

At this time NRSI is satisfied with the replacement material and the planting implementation. A follow-up inspection will be conducted in 2015 in conjunction with the inspection of additional deciduous trees to be planted.

I trust the above information is adequate. Should you have any questions or comments, please do not hesitate to contact the undersigned.

Sincerely,
Natural Resource Solutions Inc.

Pat Deacon, B.E.S.
Terrestrial and Wetland Biologist

Photo 1: Eastern white cedar replacement stock at rear of residence on Teal Drive.

Photo 2: Area of cut staghorn Sumac at west end of hedgerow.

Annual Technical Memorandum
Groundwater Monitoring Program
for 2014
Hanlon Creek Business Park
City of Guelph

April 2015

Prepared for:

City of Guelph
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Technical Memorandum

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27 April 2015

Hanlon Creek Business Park
2014 Groundwater Monitoring Program

1 Introduction

This Technical Memorandum presents the results of the seventh year of a long-term groundwater monitoring program for the Hanlon Creek Business Park (HCBP). The results of the first six years were presented in Technical Memoranda completed in 2009 through 2014 respectively. A Hydrogeology Report was completed by Banks Groundwater Engineering Limited in May 2008, as part of the Environmental Implementation Report (EIR), in support of the proposed HCBP. The Hydrogeology Report presented a recommended long-term groundwater monitoring program. This program was developed in recognition of the importance of establishing baseline groundwater conditions and to assess any changes in groundwater elevations and groundwater quality during and following development of the site. The monitoring program is also required to assess the performance of the stormwater management facilities as they are constructed and to observe seasonal trends in water levels in the core wetland. This monitoring program is consistent with the recommendations of the Hanlon Creek State-of-the-Watershed Study Report (2003).

Baseline groundwater conditions were established during five years of on-site monitoring. The detailed results for the period spring 2003 to spring 2008 were presented in the Hydrogeology Report. Banks Groundwater Engineering is continuing to monitor groundwater in on-site monitoring wells and in wetland and streambed mini-piezometers on a quarterly basis. To correspond to previous monitoring, the preferred monitoring periods are January, April, July and October. Data loggers have been installed to measure and record groundwater levels and temperatures on a more frequent basis in selected monitoring wells and mini-piezometers. Groundwater samples are being collected from selected monitoring wells on an annual basis and analyzed for a representative list of groundwater quality parameters to augment the existing background water quality data.

It is not expected that development of this site will have any effect on local private water wells. It is expected that if any changes in groundwater elevations and groundwater quality occur during and following development of the site, as a result of construction and post-construction activities, they will become apparent first in the on-site monitoring wells. Therefore, it was concluded that monitoring of local private wells was not required.

It is also noted that selected monitoring wells and mini-piezometers are currently being monitored for the purpose of establishing baseline data in advance of proposed adjacent land use activities (e.g. Mast-Snyder Gravel Pit). Changes related to climatic conditions are being observed in the on-site monitoring wells and mini-piezometers.

Site grading began in 2010 in Phases 1 and 2. This necessitated decommissioning of selected monitoring stations located within the grading areas, in accordance with Ontario Regulation 903 (as recently amended) of the Ontario Water Resources Act by a licensed Water Well Technician. Records of well decommissioning are required by this Regulation to be completed and submitted to the Owner and the Ministry of the Environment and Climate Change (MOECC).

A total of 12 monitoring wells had been decommissioned by the end of 2011, three monitors were located in Phase 1 and the remaining nine monitors were located in Phase 2.

Many existing monitoring wells have been maintained, with minor modifications or improvements, for continued monitoring. Six new monitors were installed within Phase 1 in October 2011, and five new monitors were installed within Phase 2 in January 2012. Monitoring of the eleven new wells began in January 2012.

The monitoring data has been compiled, plotted, and analyzed and the results are presented in this Technical Memorandum. Conclusions and recommendations related to the monitoring program are summarized.

2 Groundwater Monitoring

2.1 Groundwater Monitoring Background

Groundwater level monitoring was conducted at this site for more than five years in support of the evaluation of local hydrogeological conditions. The various stages of monitoring that have been completed are summarized in the EIR Hydrogeology Report. Since January 2007, groundwater levels have been monitored at the HCBP site on a quarterly basis.

The locations of the current groundwater monitoring stations are shown in Figure 1. As noted above, some stations have been decommissioned and new stations were installed as of January 2012.

2.2 Groundwater Monitoring Stations Status

The status of each groundwater monitoring station is determined during each monitoring round. This includes all monitoring wells and mini-piezometers. The current condition of each station and other relevant attributes are described in Appendix A. Monitoring wells decommissioned during 2010 and 2011 are identified. New monitoring wells and mini-piezometers in Phases 1 and 2 are also included.

2.3 Groundwater Monitoring Data Collection and Compilation

The establishment of baseline groundwater conditions continued until grading of the site was initiated. This included monitoring of groundwater levels in selected monitoring wells and mini-piezometers (listed in Appendix A). In most cases this monitoring will continue to occur on a seasonal basis to establish variations in groundwater levels for each season at each station. In a selected number of monitors, groundwater levels and temperatures will also continue to be recorded on a frequent basis using data loggers. This will assist in determining the relationships of groundwater levels, wetland levels, surface water flow, and precipitation. Groundwater samples were collected from selected monitoring wells and analyzed for general chemical parameters in 2014. Sampling and analysis is to continue on an annual basis.

During the 2014 monitoring period, there were 37 functioning monitoring wells and 19 mini-piezometers located across the HCBP site. Two of the mini-piezometers were installed in June 2013 on a temporary basis, and remained in-place at the end of 2014 (details below). The data obtained from all groundwater monitoring locations during 2014 were compiled for the purpose of the analyses presented below.

Following each seasonal monitoring period, the data was recorded and entered into the groundwater level and temperature monitoring dataset. Data downloaded from each data logger was corrected for barometric pressure and then incorporated into the respective records within the groundwater level monitoring dataset. As the dataset is updated, tables and graphs are also updated to support on-going analysis of the groundwater monitoring results.

2.4 Groundwater Monitoring Results

The results of manual groundwater level measurements at the HCBP site up to October 2014 are summarized in tabular format in Appendix B. Selected monitoring station details are included with the monitoring data, which is presented as depth (in metres) to groundwater below current ground level and groundwater elevation (metres above mean sea level).

The groundwater elevation data for each monitoring station, based on the manual measurements, are presented in graphical format in Appendix C. The groundwater elevations from April 2003 to October 2014 presented in these graphs illustrate seasonal levels for most locations. The range of groundwater elevations varies with each monitoring location, ranging from as little as 0.45 m, to as much as 2.53 m over this 11.5-year monitoring period. Monitoring well MW123 is excluded from this comparison as it is completed in the deep bedrock aquifer and the groundwater levels are influenced by municipal well production.

Presented in Appendix D is a summary of vertical hydraulic gradient calculations, based on comparisons of shallow, intermediate and deep monitoring intervals, on selected dates. Graphs illustrating groundwater elevations and hydraulic gradients are included, with monitoring stations grouped in seven west-to-east profiles. These data and graphs confirm the downward hydraulic gradients (i.e. groundwater recharge conditions) in the upland portions of the site, and upward hydraulic gradients in the vicinity of, and within, the core wetland complex (i.e. groundwater discharge conditions). Groundwater discharge conditions have also been confirmed at the wetland adjacent to Downey Road, situated between Laird and Forestell Roads.

Given that climate is one of the most significant factors influencing groundwater elevations, available local climate data was compiled and is presented in graphical format in Appendix E. During 2014, groundwater elevations and temperatures were recorded using data loggers in 38 groundwater monitoring stations. These data are presented with the climate data in Appendixes F, G, and H.

The hourly groundwater elevation data presented in Appendixes F, G, and H has been further assessed by reducing the data into graphs of the quarterly (i.e. seasonal) range in hourly groundwater elevations for each of the currently-existing monitors that are equipped with data loggers for part or all of the period from 2007 to 2014. This format is intended to assist in illustrating any significant changes and/or trends in the data when compared year-over-year for each quarter. This is the first report to include such graphs, which are presented in Appendix I.

Groundwater samples have been collected from selected monitoring wells in July 2003 and each April from 2008 to 2014. The samples were submitted to an accredited laboratory for analysis of selected chemical parameters. As indicated previously, this will provide a baseline of groundwater quality data prior to and during development of the site. The water quality data are presented in Appendix J.

3 Groundwater Characterization Update

3.1 Factors Influencing Fluctuations in Groundwater Elevations

There are a number of factors that influence groundwater levels at any given time and location, including:

- Precipitation
- Ambient air temperature and solar radiation (influencing snowmelt, evaporation and evapotranspiration)
- Vegetation
- Soils
- Geology
- Topography and associated drainage characteristics

- Land cover
- Local groundwater withdrawals and uses (e.g. construction dewatering).

Each of these factors can influence the rate and spatial distribution of groundwater recharge. As such, it was important to account for these factors under the pre-development conditions in order to appreciate the causes of observed groundwater elevation changes. These changes also need to be evaluated relative to long-, medium-, and short-term influences. For the purposes of this evaluation, a long-term influence is considered for example to be lower-than-normal precipitation over several years, which have caused drought conditions in this area of Ontario historically and recently. For the purposes of this evaluation, medium-term influences are considered seasonal. Short-term influences are considered event-related, such as spring thaw and periods of above-normal or sustained rainfall.

Given that climate is one of the most significant factors influencing groundwater elevations, available local climate data was compiled and plotted to evaluate short-, medium-, and long-term variations and trends in precipitation and air temperature. A detailed evaluation of climate and fluctuations in groundwater elevations was presented in the EIR Hydrogeology Report.

Updated climate data is presented in graphical format in Appendix E. Graph E1 presents the total annual precipitation recorded at the Region of Waterloo International Airport Station (WMO ID 71368), for the period 1971 to 2014 inclusive. This station was selected due to its' proximity to the HCBP site and availability of total daily precipitation and maximum daily air temperature data. Also illustrated in Graph E1 is a trend line depicting the annual cumulative departure from the average annual precipitation for this 44-year period, which is estimated to be 883 mm/year. This technique is helpful in illustrating periods of above- and below-average annual precipitation. An upward trend indicates sequential years of above-average precipitation (e.g. 1982 to 1988). A downward trend indicates a period of below-average precipitation (e.g. 1997 to 2007), possibly resulting in drought conditions. These longer-term trends can have a notable influence on groundwater levels. They need to be considered in the context of past, present, and future groundwater levels on-site due to the relatively shorter period (i.e. less than 12 years) of groundwater monitoring that has been conducted at the HCBP site.

The data presented in Graph E1 indicates that during the period 1997 to 2014 inclusive, the total annual precipitation for 12 out of 18 years was below the 44-year average of 883 mm/year. It is therefore interpreted that groundwater levels would have been elevated during the early to mid-1990's and likely declined from 1997 to 2007. Since groundwater monitoring began on-site in 2003, the total annual precipitation has been above the longer-term annual average in the years 2003, 2006, 2008, 2011, and 2013. The varying annual precipitation during this period has caused groundwater levels to continue to fluctuate.

As indicated above, the groundwater monitoring program on-site began in April 2003. It is therefore useful to consider total monthly precipitation during this period (and shortly before) to evaluate medium-term influences on groundwater levels. Graph E2 presents the total monthly precipitation recorded at the Region of Waterloo International Airport Station, for the period January 2003 to December 2014 inclusive. Also illustrated in Graph E2 is a trend line depicting the monthly cumulative departure from the average monthly precipitation for this period. The average monthly precipitation for the period 2003 to 2014 has been calculated to be about 69 mm/month. Similar to the annual data, an upward trend indicates sequential months of above-average precipitation, which may cause increases in groundwater levels. A downward trend indicates a period of below-average precipitation, possibly resulting in a reduction in groundwater levels. On the basis of Graph E2, it would be expected that groundwater levels would be higher following months of above average precipitation (e.g. October through December 2007, June through December 2008, April through August 2009, August through December 2011, September through October 2012, April through July 2013, and April, July and September 2014).

The monthly observed precipitation from January 2003 to December 2014, the monthly normal's, and the cumulative departure from the normal monthly precipitation are presented in Graph E3. This plot suggests that, due to a declining trend in precipitation from the spring of 2004 to the spring of 2008, groundwater levels would have declined during the same period, followed by an increase from the summer of 2008 to the summer of 2009, when monthly precipitation was greater. Increases in groundwater levels would also be expected in the spring of 2010, the fall of 2011, the fall of 2012, the spring and fall of 2013, and in the summer and fall of 2014.

An alternative method to evaluate fluctuations in groundwater levels relative to monthly precipitation trends is to consider the monthly cumulative departure from normal monthly amounts. The normal amounts are based on the updated 30-year record (i.e. from 1981 to 2010), which was published in 2013 by Environment Canada. The updated record was applied in preparation of Graph E3.

These observations are further illustrated in Graph E4, which presents the preceding 18-month average monthly precipitation for the period from January 2003 to December 2014. This graph was developed with the understanding that the preceding 18 months of precipitation are likely the most influential on observed groundwater elevation trends. The cumulative departure from the 18-month average precipitation over this period also emphasizes the trends observed in Graph E2. One of the most notable recent trends is the increase in average precipitation beginning in the second half of 2008 and continuing to July 2009. This was followed by fluctuations up to December 2014, including a declining trend from August 2009 to the end of May 2010 and somewhat of a rebound from June to October 2010, a continued rise during August through December 2011, a sharp decline from December 2011 to September 2012, then a significant rise from March to October 2013, and another rise from June to October 2014. The increase in 2014 represents the second highest level since monitoring began in 2003.

Short-term influences related to events are depicted by daily precipitation totals and ambient air temperature (i.e. maximum daily temperature). These data are presented in Graph E5, for the March 2007 to December 2014 monitoring period, and in Graph E6 for the January to December 2014 period. To determine which events have an immediate influence on groundwater levels, total daily precipitation and air temperature are plotted together and compared with groundwater levels. Based on available data, the relationship of the above factors to observed fluctuations in groundwater elevations within the HCBP site was evaluated with direct reference to Graphs E1 to E6 and graphs of groundwater elevations observed at each monitoring station. This analysis is presented in the following sub-sections.

3.2 Observed Groundwater Elevations and Depths to Groundwater

The manually-recorded groundwater elevations for each monitoring station are summarized in tabular form in Appendix B, and presented as graphs in Appendix C. Groundwater elevations recorded by data loggers installed in 38 of the active monitoring locations are presented as graphs in Appendixes F, G, and H. Graphs for monitoring stations that have been decommissioned are also included for reference in Appendixes C, G and H. The observed groundwater elevations can be associated with the long-, medium-, and short-term factors discussed previously. To assist with the direct comparison of groundwater elevations and precipitation, the total monthly precipitation has been included in each of the graphs in Appendixes F, G, and H. The interpreted relationships are discussed below.

3.2.1 Long-Term

Analyses presented in the six previous Technical Memoranda and the EIR Hydrogeology Report showed that it is likely groundwater levels declined from the spring of 1997 to the fall of 2007, based on the recorded precipitation for this period. Evidence of the effects of the longer trend of below-average precipitation is shown by the groundwater levels in July and November 2007, which prior to 2012 were the lowest observed groundwater elevations on-site. Precipitation in 2007 was well below average and was the lowest observed from 1971 to 2014 (refer to Graph E1). Below-average annual precipitation in 2009 and 2010 also influenced groundwater elevations through the summer and fall of 2010. The total precipitation in 2012 was 684 mm, which was the fourth lowest recorded amount from 1971 to 2014.

This was attributed to below-average precipitation in nine of twelve months in 2012. Groundwater levels at many monitored locations on-site during the summer and fall of 2012 were the lowest recorded since monitoring began in 2003.

In contrast, annual precipitation in 2003, 2006, 2008, 2011, and 2013 was above average. This appears to have influenced groundwater levels in the spring of 2004 and 2007, the spring and fall of 2008, in the last five months of 2011, and from spring to fall in 2013.

3.2.2 Medium-Term

Analyses presented in the six previous Technical Memoranda and the EIR Hydrogeology Report showed that monthly total precipitation and trends (depicted in Graphs E2 and E3) provide additional insight related to the observed seasonal fluctuations in groundwater elevations. Following below-average precipitation in late 2009, through most of 2010, and into February 2011, groundwater elevations declined and approached the low levels observed in 2007. Above-average precipitation from March to December 2011 (with the exception of July), reversed the declining groundwater levels at many locations. But then the below-average precipitation through seven of the first eight months of 2012 caused groundwater levels to decline, and at many locations to the lowest recorded since monitoring began in 2003. These effects were reversed following above-average monthly precipitation in September and October 2012, and April, June, July, and October 2013.

Throughout 2014, maximum daily temperatures fluctuated within the typical seasonal ranges. During the second week of January, maximum daily temperatures were above 0^0C on five consecutive days and about 20 mm of rain occurred during this time. This brief thaw and precipitation caused an observed increase in groundwater levels on-site in most monitors. Another brief thaw occurred during the third week of February, and with about 10 mm of rain caused another increase in groundwater levels. Maximum daily temperatures began rising slowly in early March and were above freezing for most of the remaining days of the month, which continued through to mid-November. The spring melt combined with above-average precipitation in April caused groundwater levels to rise higher. Groundwater levels began the typical decline in May. Precipitation events in July resulted in short-term groundwater level increases, but levels continued to decline until events in early-September and October caused groundwater levels to rise and fluctuate through November.

3.2.3 Short-Term

The manual measuring and recording of groundwater levels across the HCBP site has been conducted on 41 occasions, during various months and seasons, from April 2003 to October 2014. As a result, monitoring of groundwater levels may not have occurred at precisely the best time to observe the highest and lowest annual elevations. Fortunately however, groundwater levels were observed in selected monitors in the spring of 2003, in most monitors in the springs of 2004 and 2006, and in all available monitors during the spring from 2007 to 2014 inclusive. Therefore, it is expected that these observations represent the influence of spring thaw and precipitation events, and as such are reasonably close to the highest annual levels for this monitoring period.

To evaluate the response to spring thaw and precipitation at selected groundwater monitors, data loggers were installed to record groundwater levels on a more frequent basis. Table 1 below lists the monitoring wells and mini-piezometers where 38 data loggers were in operation for all of 2014 (refer to Figure 1 for locations). A number of locations were selected to evaluate groundwater levels and to establish baseline conditions relative to various climate effects prior to development of the HCBP.

The EIR Hydrogeology Report presented a detailed evaluation of daily influences from March 2007 to April 2008. The previous six Technical Memoranda presented a detailed evaluation of climate influences on groundwater levels for January through December of 2008, 2009, 2010, 2011, 2012, and 2013 respectively. For reference, the total daily precipitation and maximum daily air temperature recorded at the Region of Waterloo International Airport Station are presented in Graph E5, for the period March 2007 to December 2014.

The following is noted for January through December 2014 in Graph E6:

- It is interpreted that the combined snowfall and rain through January, February and March was equivalent to about 102 mm of precipitation, which is about 80 mm below the normal amount for this three-month period
- Maximum daily temperatures began rising slowly in early March and were above freezing for most of the remaining days of the month. The spring melt was combined with precipitation of about 89 mm in April, which was above the normal of 74.5 mm.
- May and June rain was a combined total of about 107 mm, compared to a combined normal of 164.7 mm. But July was above the normal of 98.6 mm, with a total of almost 170 mm over the month. August received less than the normal of 83.9 mm, with 65.1 mm of rain. September precipitation was also well above the normal of 87.8 mm, with almost 180 mm of rain.
- October received a normal amount of rain, but was followed by a combined lower-than-normal amount in November and December. A precipitation total of about 51 mm was less than one-third the normal combined amount of 158.3 mm for these two months.
- Total precipitation was above-normal for the months of April, July, and September. Total monthly precipitation was below normal amounts for the other nine months.
- The few days of maximum daily temperatures that were above freezing during January and February is interpreted to have resulted in melting of the snow pack, and when combined with rainfall events, increased the potential for groundwater recharge. Groundwater levels increased above the fall 2013 levels.
- Maximum daily air temperatures remained above 0^0C for most days from early-March to mid-November 2014.
- The total precipitation through 2014 was about 826 mm, as compared to a 44-year average of about 883 mm.

These are considered to be the main climatic factors influencing groundwater levels on-site during the 2014 interval. The highest groundwater levels observed in monitors equipped with data loggers occurred during the months of January, April, September, and November. The lowest groundwater levels occurred in early-March, early-September and early-November, in contrast to previous years.

Table 1: Monitoring Stations Equipped With Data Loggers as of December 2014

Monitoring Well	Data Logger Installed	Monitoring Well	Data Logger Installed
003	March 2007	122A	July 2008
004	August 2009	124	January 2012
103	June 2010	125	January 2012
104	January 2008	126	January 2012
105	January 2008	127	January 2012
107	July 2008	128	January 2012
109	April 2009	129	January 2012
111	October 2010	130A	January 2012
112	October 2010	131	January 2012
116A	January 2008	132	January 2012
117A	January 2008	133	January 2012
118A	July 2008	134	January 2012
119A	July 2008	135	January 2012
121A	July 2008		

Mini-Piezometer	Data Logger Installed	Mini-Piezometer	Data Logger Installed
1D	April 2009	10D	April 2012
2D	January 2007	11D	June 2010
4D	April 2009	12D	January 2012
7D	November 2007	13D	June 2013
8D	June 2010	14D	June 2013
9D	March 2007		

2014 Groundwater Level Monitoring at Downey Road PSW

Groundwater levels and temperatures are monitored at two stations at the Downey Road PSW. These include monitoring well MW003, which is located on the north edge of the PSW, and mini-piezometer nest PZ-9, which is located in the centre of the PSW. The groundwater level and temperature observations for MW003 and PZ-9D are presented in graphical format in Appendix F.

Graph F1 presents the daily groundwater elevations (with occasional manual readings) recorded in monitor MW003, from March 2007 to January 2008. In late January 2008, the data logger was re-set to record groundwater levels and temperatures on an hourly basis. The EIR Hydrogeology Report presented a detailed evaluation of groundwater levels from March 2007 to April 2008, and the six previous Technical Memoranda presented a detailed evaluation for each respective year from 2008 through 2013. The following is a summary of 2014 observations at this location.

During the months of January, February and March 2014, groundwater levels were within the typical range for this time of year, fluctuating in direct response to maximum daily temperatures above 0^0C and corresponding periods of infiltrating precipitation. As noted previously, the combined snowfall and rain through January, February and March was equivalent to about 102 mm of precipitation, which is about 80 mm below the normal amount for this three-month period. However, the brief thaws in January and February caused groundwater levels to rise to within about 20 cm of the highest observed at this location. Groundwater levels began a gradual decline in mid-May, with occasional short-duration increases in response to precipitation events measuring more than 15 mm in a 24-hour period. Groundwater levels rose in response to precipitation in early-September and again in October.

The responses to precipitation events and spring thaw, or lack thereof, observed in this monitor during the period 2007 to 2014, have demonstrated the local sensitivity of the shallow groundwater system, which is associated with the coarse-grained nature of the overburden deposits within and above the uppermost aquifer. The below-normal precipitation during 2014 had a negligible effect on groundwater levels at this location.

Two mini-piezometers were installed in the Downey Road PSW. PZ-9S was installed to a depth of about 0.5 m and PZ-9D to a depth of about 1.0 m below ground level. Graph F2 presents the groundwater elevations recorded in mini-piezometer PZ-9D, for the period March 2007 to December 2014. Groundwater levels for this pair of shallow and deeper mini-piezometers have illustrated the upward hydraulic gradient that exists in this PSW.

It is noted that responses to precipitation and temperature are apparent in PZ-9D in Graph F2, similar to MW003, confirming the infiltrative capacity of the medium- to coarse-grained deposits on this site and the inherent relationship of the wetlands to the shallow groundwater system. Each year, groundwater levels decline to an elevation that is below ground level in the wetland, typically during June or July.

The groundwater elevations for MW003 and PZ-9D are combined in Graph F3, indicating similar trends in each monitor. A small upward hydraulic gradient is also evident at various times when groundwater levels in MW003 are higher when compared with levels in the adjacent PZ-9D.

2014 Groundwater Level Monitoring in the Core PSW

Groundwater level and temperature observations, for monitoring wells and mini-piezometers that are located in and adjacent to the Core PSW of the HCBP, are presented in graphical format in Appendix G. The total monthly precipitation has been included for comparison in the groundwater elevation graphs. The maximum daily air temperature trend has been included for comparison in the groundwater temperature graphs. The graphs in Appendix G are presented in an order that corresponds to the north-to-south locations of the monitoring stations (refer to Figure 1).

The responses to maximum daily air temperatures and precipitation are apparent in these plots. This confirms the infiltrative capacity of the medium- to coarse-grained deposits adjacent to the Core PSW and the inherent relationship of the wetlands to the shallow groundwater system. The hourly recording of groundwater levels at mini-piezometer locations also indicates subtle fluctuations during each 24-hour period, likely associated with diurnal cycles of evapotranspiration in the wetland. The range of groundwater levels in mini-piezometers is more subdued than other plots, which reflects the relatively constant groundwater elevations in the wetland area, usually with only minor perturbations observed relative to precipitation and/or temperature changes.

The observed relationship of total daily rainfall and maximum daily temperature, recorded at the Region of Waterloo International Airport Station, to the groundwater levels and temperatures recorded on-site continues to validate the use of this station's data for these analyses.

Groundwater levels at Core PSW monitoring stations during 2014 responded to climatic factors similar to the Downey Road PSW monitors described in the previous section. During the months of January, February and March, groundwater levels were within the typical range for this time of year, fluctuating in direct response to maximum daily temperatures above 0^0C and corresponding periods of infiltrating precipitation. As noted previously, the combined snowfall and rain through January, February and March was equivalent to about 102 mm of precipitation, which is about 80 mm below the normal amount for this three-month period. However, the brief thaws in January and February caused groundwater levels to rise.

Groundwater levels began a gradual decline in mid-May, with occasional short-duration increases in response to precipitation events measuring more than 15 mm in a 24-hour period. The lowest levels observed in 2014 varied from location to location, but most occurred during late-August and early-September. At almost all locations where data loggers had been in place for more than three years, the 2014 summer levels were comparable to 2013 summer levels, which were above the low levels observed during the drought in the summer of 2012. At many Core PSW monitoring stations, groundwater levels rose in response to precipitation in early-September and again in October.

Groundwater levels in the three mini-piezometer monitoring locations (i.e. from north to south PZ-4D, PZ-2D, and PZ-1D) that are located in the Core PSW, were below the normal range for most of 2012. During 2013 and 2014, groundwater levels were within the range of previous years. The recorded groundwater elevations for PZ-4D, PZ-2D, and PZ-1D are presented in Graphs G13, G20, and G22 respectively. These graphs show groundwater levels that are typically at, or above, ground level during spring months and reduced levels during late-summer months.

Similarly, groundwater levels recorded in streambed mini-piezometers (i.e. from north to south PZ-10D, PZ-8D, PZ-11D, PZ-7D) were below the level of the creek and the streambed for part, if not most, of 2012. Groundwater levels during 2013 and 2014 were within the range observed in previous years, where data is available. The recorded groundwater elevations for PZ-10D, PZ-8D, PZ-11D, and PZ-7D are presented in Graphs G2, G4, G6, and G8 respectively. These graphs show groundwater levels at, or above, the streambed during spring months and reduced levels during late-summer months.

Climate had the greatest, if not only, influence on groundwater levels within the Core PSW in 2014. There were no apparent short-term and/or longer-term changes in groundwater levels that could be attributed to construction activities during 2014 within the HCBP (i.e. there were no abnormal changes in groundwater elevations that would have suggested otherwise). As of the end of 2014, five lots in

Phase 1 had been developed and another six were at various stages of development. The remainder of the graded portion of the site consisted of paved roadways, vegetated stormwater management swales and ponds, gravel-surfaced trails, and barren soils across most vacant lots. Based on the observed responses of groundwater levels to rainfall events and above-normal total monthly precipitation during April, July, and September, it is evident that infiltration was occurring across the site.

2014 Groundwater Level Monitoring at Perimeter Locations

Groundwater level and temperature observations, for monitoring wells that are located at perimeter locations around the HCBP site, are presented in graphical format in Appendix H. The total monthly precipitation has been included for comparison in the groundwater elevation graphs. The maximum daily air temperature trend has been included for comparison in the groundwater temperature graphs. The graphs in Appendix H are presented in an order that corresponds to the north-to-south locations of the monitoring stations (refer to Figure 1).

The responses to precipitation and maximum daily air temperatures are also apparent in these plots. Groundwater elevations vary more widely over the year at perimeter locations in comparison to the Core PSW locations. The perimeter groundwater monitoring stations responded to the above-normal precipitation during April, July, and September 2014, similar to the monitoring stations described in the previous two sections. There were no apparent short-term and/or longer-term changes in groundwater levels at perimeter monitoring stations that could be attributed to construction activities during 2014 within the HCBP.

3.2.4 Site-Wide Observations

Groundwater Elevations

It is noted that, as expected, the greatest range in groundwater elevations occurs around the perimeter locations of the site where groundwater recharge to the medium- to coarse-grained deposits is most significant. The smallest fluctuations occur in and adjacent to the core wetland and Hanlon Creek Tributary 'A'. Shallow depths to groundwater and the occurrence of groundwater discharge to these surface water features naturally limit the range of groundwater elevations in these areas.

The hourly groundwater elevation data presented in Appendixes F, G, and H has been further assessed by reducing the data into graphs of the <u>quarterly (i.e. seasonal) range in hourly groundwater elevations</u> for each of the currently-existing monitors that are equipped with data loggers for part or all of the period from 2007 to 2014. This format is intended to assist in illustrating any significant changes and/or trends in the data when compared year-over-year for each quarter/season. This is the first report to include such graphs, which are presented in Appendix I.

The graphs in Appendix I are presented in numerical order, with monitoring wells presented first and then followed by piezometers (refer to Figure 1). The responses to short-, medium- and longer-term precipitation amounts are apparent in these plots. There are no apparent changes in groundwater levels at these monitoring stations that could be attributed to construction activities within the HCBP, with the exception of those monitors affected by short-term construction dewatering events in 2010, 2011, and 2012. Therefore, it is recommended that this format continue to be utilized to track fluctuations in groundwater elevation trends as part of the long-term monitoring program.

Depth to Groundwater

The smallest fluctuations in depth to groundwater occur in and adjacent to the core wetland and Hanlon Creek Tributary 'A'. Shallow depths to groundwater and the occurrence of groundwater discharge to these surface water features naturally limit the range in depths to groundwater in these areas. The greatest range in depths to groundwater occurs around the perimeter locations of the site where groundwater recharge to the medium- to coarse-grained deposits is most significant.

Groundwater Flow

The EIR Hydrogeology Report illustrated the horizontal direction of shallow groundwater flow is from southeast of the site, arcing towards the northern boundary of the site. The horizontal direction of groundwater flow coincides with the wetlands and creek, indicating that a portion of groundwater is discharging to this surface water system.

Also of interest is the vertical direction of groundwater flow. Presented in Appendix D is a summary of vertical hydraulic gradient calculations, based on comparisons of shallow, intermediate and deep monitoring intervals, on selected dates. Graphs illustrating groundwater elevations and hydraulic gradients are included, with monitoring stations grouped in seven west-to-east profiles. These data and graphs confirm the downward hydraulic gradients (i.e. groundwater recharge conditions) in the upland portions of the site, and upward hydraulic gradients in the vicinity of, and within, the core wetland complex (i.e. groundwater discharge conditions). Seasonal variations in vertical directions of groundwater flow are also observed in some monitoring well pairs. Groundwater discharge conditions have also been confirmed at the Downey Road PSW.

3.2.5 Groundwater Temperatures

Data loggers installed in either a monitoring well or mini-piezometer also record groundwater temperature. These data are illustrated in graphical format in Appendixes F, G, and H, following the groundwater elevation graphs. The maximum daily air temperature trend has been included for comparison in these groundwater temperature graphs. Seasonal variations and associated time lags in groundwater temperatures are illustrated by these graphs.

PSW Groundwater Temperature Monitoring

As noted previously, groundwater level and temperature monitoring has been conducted using data loggers since 2007 at four PSW monitoring locations (i.e. MW003, PZ-9D, PZ-2D, and PZ-7D). These locations are representative of shallow groundwater conditions, although each location has somewhat different characteristics. The characteristics and factors that may influence groundwater temperatures are described as follows:

- MW003 – completed in the shallow water table aquifer; groundwater levels have ranged from 0.3 m above grade to 1.3 m below grade; located at the edge of an open agricultural field, adjacent to a provincially significant wetland (PSW); shallow groundwater temperature recorded is potentially influenced by cold air temperatures during winter months and by sunlight and standing water in the wetland during summer months (Graphs F 1 and F 1a, Appendix F)
- PZ-9D – relatively shallow (i.e. 1.0 m deep) mini-piezometer; groundwater levels have ranged from 0.62 m above grade to 0.88 m below grade; located in the PSW close to MW003; shallow groundwater temperature recorded is potentially influenced by cold air temperatures and frozen wetland during winter months and by sunlight and standing water in the wetland during summer months (Graphs F 2 and F 2a, Appendix F)
- PZ-2D – relatively shallow (i.e. 1.0 m deep) mini-piezometer; groundwater levels have ranged from 0.04 m above grade to 0.80 m below grade; located in a core wetland complex about 50 m east of Hanlon Creek Tributary ‘A’; shallow groundwater temperature recorded is potentially influenced by cold air temperatures during winter months and moderated by trees providing shade during summer months (Graphs G 20 and G 20a, Appendix G)
- PZ-7D – relatively shallow (i.e. 1.0 m deep) mini-piezometer; groundwater levels have ranged from 0.25 m above grade to 0.05 m below grade; located in a core wetland complex in the eastern tributary of Hanlon Creek Tributary ‘A’; shallow groundwater temperature recorded is potentially influenced by cold air temperatures during winter months and moderated by trees providing shade during summer months (Graphs G 8 and G 8a, Appendix G)

Temperatures recorded from March 2007 to December 2014 at these locations range from a low of just below 3^0C to a high of almost 16^0C. The 2014 temperature ranges for each location were as follows:

- MW003 – similar to previous years ranging from a low of 5.7^0C in late-March to a high of 12^0C in late-October
- PZ-9D – ranged from a low of 2.8^0C in late-March to a high of 14.2^0C in mid-September
- PZ-2D – ranged from a low of 3.9^0C in mid-April to a high in mid-September of 13.2^0C
- PZ-7D – ranged from a low of 4.8^0C in early-March to a high of 11^0C in late-August.

The temperature range of groundwater at greater depths in this general area tends to fluctuate in a narrower range, typically between 5 and 10^0C. It is therefore apparent that the temperatures in the shallower groundwater regime in the vicinity of these four monitors are influenced by seasonal variations in air temperature and solar radiation. These data are interpreted to be representative of the temperature of groundwater discharging to the wetlands and creeks in these locations.

Monitoring Well MW119A

This monitor is located adjacent to the northwest edge of stormwater management pond 4. The principal groundwater flow direction in this part of the HCBP site is north-westerly towards Tributary 'A' of Hanlon Creek. This monitor location is therefore down-gradient of pond 4. Groundwater temperatures recorded in monitoring well MW119A during 2014 ranged from a low of 5.3^0C at the start of April, to a high of 14.7^0C in mid-September (Graph G 18a, Appendix G). This is comparable to the ranges observed from 2008 to 2010. The highest temperature recorded to-date at this location was 17.5^0C on 5 September 2012. Prior to construction of pond 4 in late 2010, the highest groundwater temperature at this monitor was 15^0C in early-September 2010. The previous two years had reached a maximum of about 13^0C in September.

The pond bottom is below the shallow groundwater surface and as a result the un-lined pond is in direct contact with the local groundwater system. A portion of the water in the pond is interpreted to discharge from the pond as groundwater and flow in a north-westerly direction. Therefore, water in the pond warmed by solar radiation during summer months appears to have increased the groundwater temperature marginally in the area down-gradient of the pond. It was noted previously that the groundwater temperature at monitoring well MW119A at the end of December 2012 was 10^0C, compared to about 7 to 8^0C on the same date the preceding four years.

Additional monitoring of groundwater temperatures down-gradient of pond 4 was initiated in June 2013. A pair of shallow mini-piezometers (PZ-13D and PZ-14D) were installed on the east and west bank of Tributary 'A', and equipped with data loggers (refer to Figure 1). The piezometers were located a short distance down-stream from surface water monitoring station HC-A(04). The groundwater temperatures recorded in each piezometer up to the end of 2014 are presented in Graph G24a. Also included in this graph are the groundwater temperatures recorded in MW119A and MW131. MW131 is located about 130 m up-gradient of pond 4. It is apparent from comparison with the MW131 graph that the groundwater temperature at PZ-13D, and possibly PZ-14D, which reached a maximum of just less than 14^0C in mid-September, was likely influenced by the warmer shallow groundwater flow affected by pond 4. The groundwater temperature at PZ-14D may have been influenced by solar radiation during summer months on the adjacent, up-gradient field. Graph 24a also shows that temperatures in PZ-13D and PZ-14D returned to below those recorded in MW131 by late-October in 2013 and 2014.

The temperatures recorded in the remaining monitoring stations also reflect shallow groundwater temperatures near the central wetland complex and around the perimeter of the site. Temperature ranges and the timing of higher and lower temperatures are similar in most monitors. The highest observed groundwater temperatures are evident in monitors where the groundwater elevation is close to surface during summer months, particularly the monitors located in open fields. These monitors also exhibit the lowest groundwater temperatures during the late winter and early spring, when melting snow and frost infiltrate to the shallow groundwater system.

3.3 Relevance to Site Development and Stormwater Management

The observed minimum and maximum depths to shallow groundwater (i.e. water table) are presented in Appendix B for the 2003 to 2014 monitoring period. These observations indicate specific locations where there may be limitations to lot-level stormwater infiltration facilities. As noted previously, the greatest range in depths to groundwater occurs around the perimeter locations of the site where groundwater recharge to the medium- to coarse-grained deposits is most significant. It is interpreted that it is in these areas where the groundwater elevations in the spring of 1997 would have been up to 0.5 m above those observed in April 2004, April 2007, and April 2008. Therefore, allowance should be made for this potential high groundwater elevation during the design of stormwater infiltration facilities, at the Site Plan Approval stage. The design should be in accordance with the Ministry of the Environment Stormwater Management Planning and Design Manual 2003, thus allowing adequate separation between the bottom of the infiltration system and the high water table elevation.

The site will be graded for development purposes. It will therefore be necessary to consider the estimated depth to groundwater based on proposed site grading to further evaluate potential locations for lot-level stormwater infiltration facilities. Continued monitoring of groundwater levels at all functioning monitoring well locations is required to support these evaluations, which will be required as part of the Site Plan Approval process.

3.4 Groundwater Quality

Groundwater samples were first collected in 2003 from 23 selected monitoring wells, and then from 33 selected monitoring wells in 2008, 2009, and 2010, and 25 available monitoring wells in 2011. A total of 36 monitoring wells were available for sampling in 2012 and 2013, including the 11 new monitoring wells. These wells were sampled again in 2014. The groundwater quality data are summarized in Appendix J. The data were compared to the Ontario Drinking Water Quality Standards (ODWQS), Ontario Regulation 169/03. Concentrations that exceeded the ODWQS are indicated on the tables. The groundwater can be characterized as basic (i.e. pH>7) and, based on the reported calcium and magnesium concentrations, as hard.

In general, the concentrations of the parameters analyzed were below the applicable ODWQS criteria, with the following exceptions (refer to Appendix J for specific exceedances and Figure 1 for well locations):

- Nitrate (as N) concentrations exceeded the ODWQS of 10.0 mg/L on at least one occasion in six monitoring wells
- Aluminum concentrations exceeded the ODWQS of 0.1 mg/L on at least one occasion in 24 monitoring wells
- Cadmium concentrations exceeded the ODWQS of 0.005 mg/L on at least one occasion in 11 monitoring wells
- Iron concentrations exceeded the ODWQS of 0.3 mg/L on at least one occasion in 32 monitoring wells
- Lead concentrations exceeded the ODWQS of 0.010 mg/L on at least one occasion in 22 monitoring wells
- Manganese concentrations exceeded the ODWQS of 0.05 mg/L on at least one occasion in 37 monitoring wells
- Sodium concentrations exceeded the ODWQS of 20 mg/L on at least one occasion in 37 monitoring wells
- Hardness concentrations exceeded the ODWQS of 100 mg/L in all monitoring wells.

The ODWQS for nitrate is health-related and the concentrations above this level in five monitoring wells can be attributed to the agricultural use of this site and the application of nutrients. Nitrate was also elevated above normal levels in five other monitoring wells. The elimination of nutrients applied to crops would be expected to reduce levels of nitrate. Such changes have been observed in other areas of Guelph.

The ODWQS for aluminum is an operational guideline for drinking water supplies and the elevated levels detected may be attributed to monitoring wells that are not developed to a sediment-free condition. Improved filtering of samples at the time of collection since 2009 has resulted in reduced levels in all monitors.

The ODWQS for lead is a standard for drinking water supplies and the elevated levels detected may be attributed to monitoring wells that are not developed to a sediment-free condition. Improved filtering of samples at the time of collection since 2009 has resulted in reduced levels in all monitors.

The ODWQS for iron and manganese is an aesthetic objective and the elevated levels are typical of groundwater in this area of Ontario. Improved filtering of samples at the time of collection since 2009 has resulted in reduced levels in all monitors.

The ODWQS for sodium is a health-related parameter for people on sodium-restricted diets. Elevated levels of sodium and chloride are often associated with the application of road salt for de-icing purposes. The levels of chloride do not exceed the ODWQS of 250 mg/L in any of the monitors; however, the level of chloride was elevated above normal levels in many of the monitors where sodium was elevated. The source of the elevated sodium and chloride occurring in some of the monitoring wells, including one of the bedrock wells, can likely be attributed to road salting along the Hanlon Expressway, Downey Road, and possibly Forestell Road.

The ODWQS for hardness is an aesthetic objective and the elevated levels observed in all monitoring wells are typical of groundwater in this area of Ontario.

Colour, turbidity, total dissolved solids, and DOC exceeded the respective ODWQS concentrations in most of the monitoring wells. This observation is typical for monitoring wells that are not developed to a sediment-free condition. Improved filtering of samples at the time of collection since 2009 has resulted in reduced levels of some parameters.

3.5 Thresholds 2014

3.5.1 Groundwater Elevations

The manually-recorded groundwater elevations for each existing and decommissioned monitoring station are summarized in tabular form in Appendix B, and presented as graphs in Appendix C. Groundwater elevations recorded by data loggers currently installed in 38 of the monitoring locations are presented as graphs in Appendixes F, G, and H. Decommissioned monitoring stations that had been equipped with data loggers are also included in Appendixes G and H for reference. These graphs also include the total monthly precipitation to assist with the direct comparison of groundwater elevations and precipitation.

As described previously, groundwater elevations across the HCBP were affected by the lack of precipitation in 2012. However, precipitation, combined with the spring melt in 2013 and 2014, caused groundwater levels to rise across the HCBP. Throughout 2014, groundwater elevations at almost all monitoring stations remained within the respective ranges observed in previous years, and as a result, there were no thresholds observed during this monitoring period. This is further illustrated by the quarterly/seasonal range in hourly groundwater elevation graphs presented in Appendix I.

In summary, climate had the greatest, if not only, influence on groundwater elevations across the HCBP in 2014. There were no apparent short-term and/or longer-term changes in groundwater levels that could be attributed to construction activities during 2014 within the HCBP. Construction dewatering occurred on two lots in Phase 1 during 2014, and there was no effect on groundwater levels in any of the nearby HCBP monitoring wells and piezometers. As of the end of 2014, five lots in Phase 1 had been developed and another six were at various stages of development. The remainder of the graded portion of the site consisted of paved roadways, vegetated stormwater management swales and ponds, gravel-surfaced trails, and barren soils across most vacant lots. Based on the observed responses of groundwater levels to rainfall events and above-normal total monthly precipitation during April, July, and September, it is evident that infiltration was occurring across the site.

3.5.2 Groundwater Temperatures

As described in sub-section 3.2.5, data loggers installed in either a monitoring well or mini-piezometer also record groundwater temperature. These data for 38 monitoring locations are illustrated in graphical format in Appendixes F, G, and H, following the groundwater elevation graphs. The maximum daily air temperature trend has been included for comparison in these groundwater temperature graphs. Seasonal variations and associated time lags in groundwater temperatures are illustrated by these graphs.

Despite the influence of climate on groundwater elevations during 2014, groundwater temperatures fluctuated within the typical ranges at most of the 38 monitoring stations where data loggers are installed. Groundwater temperatures at monitoring stations MW119A, PZ13-D and PZ-14D, which are located down-gradient of pond 4, were likely influenced by the warmer water in this stormwater management pond in late summer. High temperatures in mid-September were 14.7^{0}C in MW119A, and at PZ-13D and PZ-14D were just less than 14^{0}C. Further comparison also shows that groundwater temperatures at PZ-13D and PZ-14D returned to below those recorded in up-gradient monitor MW131 by late-October in 2013 and 2014, whereas MW119A was similar to MW131 beginning in December both years.

3.6 Long-Term Groundwater Monitoring Program

The long-term groundwater monitoring program at the HCBP site should continue as previously recommended on a quarterly basis. As the site is graded and blocks prepared for development, new monitoring wells are installed to replace decommissioned wells. This is being completed as soon as practically possible, such that the effects of development on groundwater levels, if any, can be identified without delay. If required, mitigative measures can then be developed and implemented. A map illustrating these locations is presented on Figure 1, in the Hanlon Creek Business Park 2014 Consolidated Monitoring Report, prepared by Natural Resource Solutions Inc., AECOM, and Banks Groundwater Engineering Limited.

Data loggers have been installed in monitoring wells and mini-piezometers that are expected to remain during and following site grading. Additional data loggers are being installed in new monitoring wells as they are installed. This will improve the groundwater monitoring dataset and the establishment of the influences of climate on groundwater elevations over the short-, medium-, and long-term. Groundwater samples should continue to be collected on an annual basis from selected monitoring wells. Improvements to filtering of water samples have been successful in reducing the amount of sediment and should be continued as a standard practise.

4 Summary

The on-going monitoring of groundwater levels has provided an updated characterization of the hydrogeological conditions across the HCBP site and surrounding area, including the local occurrence and movement of groundwater in relation to the on-site wetlands and Hanlon Creek Tributary 'A'. The following is a summary of conclusions and recommendations related to the groundwater monitoring program.

- A long-term groundwater monitoring program is required to assess any changes in groundwater elevations and groundwater quality during and following development of the site. The monitoring program is also required to assess the performance of the stormwater management facilities once they are constructed and to observe seasonal trends in water levels in the core wetland. It is therefore recommended that groundwater levels continue to be monitored on a quarterly basis at a minimum in all available monitoring wells and mini-piezometers, before and where possible during grading of the site. To correspond to previous monitoring, the preferred monitoring periods would continue to be January, April, July and October. Groundwater samples should continue to be collected from all available monitoring wells to augment the existing background water quality data.
- Any monitoring stations located within grading areas must be properly decommissioned, in advance of grading, in accordance with Ontario Regulation 903, as recently amended, of the Ontario Water Resources Act, by a licensed Water Well Technician.
- In some cases, existing monitoring wells can be maintained, with minor modifications or improvements, for continued monitoring. Several monitors have been replaced following grading and development of selected blocks. The locations for long-term monitoring of groundwater levels and quality are identified, including existing and new monitors that are expected to be maintained and proposed future monitoring locations (refer to Figure 1, Hanlon Creek Business Park 2014 Consolidated Monitoring Report, prepared by Natural Resource Solutions Inc., AECOM, and Banks Groundwater Engineering Limited).
- Groundwater level and temperature monitoring using data loggers should continue for many, if not all, of the groundwater monitoring stations over the long-term. By utilizing this technology, the frequency of monitoring can be increased significantly and trends in groundwater level changes (e.g. related to construction) can be detected sooner and with improved accuracy.
- It is recommended that the monitoring data continue to be compiled, plotted, and analyzed on an annual basis by a qualified professional engineer or geoscientist. The results should be presented in a Technical Memorandum that is submitted as an Appendix to the Consolidated Monitoring Report to the City of Guelph, for the purpose of review, acceptance, and response to recommendations. Recommendations related to the monitoring program, including any proposed modifications, would be included. The GRCA should also receive a copy for review and comment in relation to maintenance of groundwater levels across the site, but with particular emphasis on the Provincially Significant Wetlands and Hanlon Creek Tributary 'A'. In the event of unexpected changes in groundwater elevations or quality, the frequency of monitoring, sampling, and reporting would be evaluated and revised as required.

Respectfully submitted,
Banks Groundwater Engineering Limited

Original signed by:

William D. Banks, P.Eng.
Principal Hydrogeologist

The Figure, Tables and Graphs referenced in this Technical Memorandum are appended under the following headings:

Figure 1: Groundwater Monitoring Stations December 2014

Appendix A: Current Groundwater Monitoring Network December 2014

Appendix B: Groundwater Level Monitoring Data 2003 – 2014

Appendix C: Groundwater Monitoring Graphs 2003 – 2014

Appendix D: Vertical Hydraulic Gradient Data and Graphs 2003 – 2014

Appendix E: Climate Monitoring Graphs 1971 – 2014

Appendix F: Downey Road PSW Groundwater Monitoring Graphs 2007 – 2014

Appendix G: HCBP Core PSW Groundwater Monitoring Graphs 2007 – 2014

Appendix H: HCBP Perimeter Groundwater Monitoring Graphs 2007 – 2014

Appendix I: HCBP Quarterly Groundwater Elevation Range Graphs 2007 – 2014

Appendix J: Groundwater Quality Monitoring Data 2003 – 2014

Figure 1

Groundwater Monitoring Stations
December 2014

Banks Groundwater Engineering Limited

Hanlon Creek Business Park
City of Guelph

Groundwater Monitoring Program

Banks Groundwater Engineering Limited
940 Watson Road South, RR 1 Puslinch, Ontario N0B 2J0
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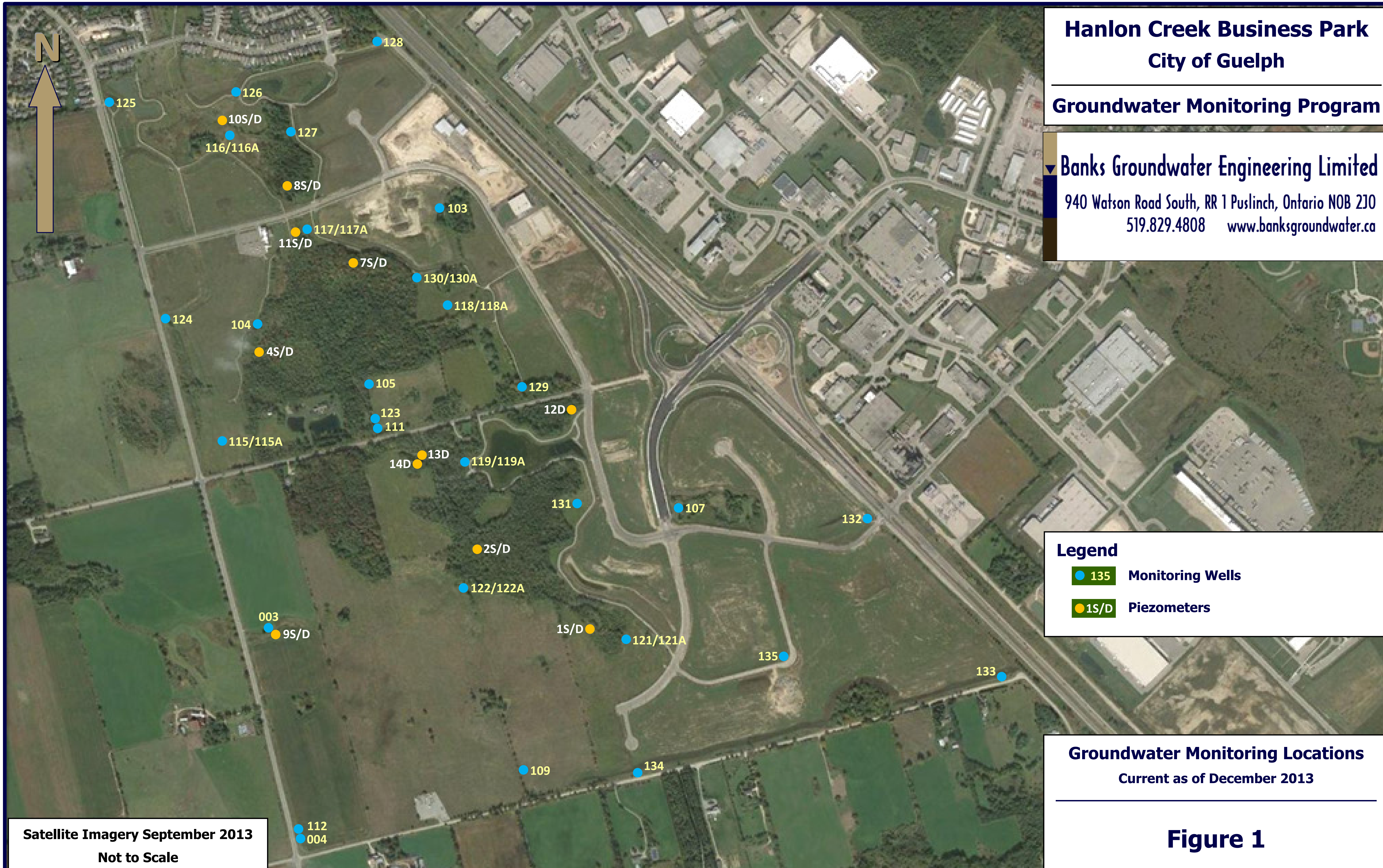

Satellite Imagery September 2013
Not to Scale

Groundwater Monitoring Locations
Current as of December 2013

Figure 1

Appendix A

Current Groundwater Monitoring Network
December 2014

Hanlon Creek Business Park - Groundwater Monitoring Program

Monitoring Well and Mini-Piezometer Condition Summary - as of December 2014

Monitoring Well Number	Type *	Nominal Well Diameter (mm)	Protective Casing Size/Diameter (mm)	Condition of Monitor & Protective Casing	Waterra Tubing In Place	Monitoring Started	Most Recent Monitoring	Data Logger Installed	Data Logger Removed
001	S	50	100	Abandoned in 2011	No	Apr-03	May-11	Jan-08	May-11
002	S	50	100	Abandoned in 2010	No	Apr-03	Oct-08	--	
003	S	50	100	Functioning; square protective casing in good condition	Yes	Apr-03	Oct-14	Mar-07	
004	S	50	100	Functioning; square protective casing in satisfactory condition	Yes	Apr-03	Oct-14	Aug-09	
005 (S)	S	13	100	Abandoned in 2010	No	Apr-03	Sep-10	--	
005 (I)	I	50	100	Abandoned in 2010	No	Apr-03	Sep-10	Aug-09	Sep-10
006	S	50	100	Abandoned in 2010	No	Apr-03	Sep-10	Aug-09	Sep-10
101	S	50	100	Abandoned in 2011	No	Jun-03	Jan-11	Jun-10	Oct-10
102	S	50	100	Abandoned in 2010	No	Jun-03	Apr-10	--	
103	S	50	100	Functioning; square protective casing in good condition	Yes	Jun-03	Oct-14	Jun-10	
104	S	50	100	Functioning; square protective casing in satisfactory condition	Yes	Jun-03	Oct-14	Jan-08	
105	S	50	100	Functioning; square protective casing in good condition	Yes	Jun-03	Oct-14	Jan-08	
106	S	50	100	Abandoned in 2012	No	Jun-03	Jul-10	Aug-09	Aug-10
107	S	50	100	Functioning; square protective casing in good condition	Yes	Jun-03	Oct-14	Jul-08	
108	S	50	100	Inaccessible	Yes	Jun-03	Apr-04	--	
109	S	50	100	Functioning; square protective casing in good condition	Yes	Jun-03	Oct-14	Apr-09	
110	I	50	100	Abandoned in 2010	No	Jun-03	Sep-10	Aug-09	Sep-10
111	D	50	150	Functioning; 150mm dia. cap, well casing in good condition	Yes	Sep-03	Oct-14	Oct-10	
112	D	50	150	Functioning; 150mm dia. cap, well casing in good condition	Yes	Sep-03	Oct-14	Oct-10	
113	D	50	150	Abandoned in 2010	No	Sep-03	Sep-10	--	
114	D	50	150	Abandoned in 2010	No	Sep-03	Sep-10	--	
115	I	50	100	Functioning; square protective casing in satisfactory condition	Yes	Jun-03	Oct-14	--	
115A	S	50	100	Functioning; square protective casing in satisfactory condition	Yes	Jun-03	Oct-14	--	
116	I	50	150	Functioning; square protective casing in satisfactory condition	Yes	Jun-03	Oct-14	--	
116A	S	50	150	Functioning; square protective casing in satisfactory condition	Yes	Jun-03	Oct-14	Jan-08	
117	I	50	100	Functioning; square protective casing in good condition	Yes	Jun-03	Oct-14	--	
117A	S	50	100	Functioning; square protective casing in good condition	Yes	Jun-03	Oct-14	Jan-08	
118	I	50	100	Functioning; square protective casing in good condition	Yes	Jun-03	Oct-14	--	
118A	S	50	100	Functioning; square protective casing in good condition	Yes	Jun-03	Oct-14	Jul-08	
119	I	50	100	Functioning; square protective casing in good condition	Yes	Jun-03	Oct-14	--	
119A	S	50	100	Functioning; square protective casing in good condition	Yes	Jun-03	Oct-14	Jul-08	
120	I	50	100	Abandoned in 2010	No	Jun-03	Apr-04	--	
120A	S	50	100	Abandoned in 2010	No	Jun-03	Apr-04	--	
121	I	50	100	Functioning; square protective casing in good condition	Yes	Jun-03	Oct-14	--	
121A	S	50	100	Functioning; square protective casing in good condition	Yes	Jun-03	Oct-14	Jul-08	
122	I	50	100	Functioning; square protective casing in good condition	Yes	Sep-03	Oct-14	--	
122A	S	50	100	Functioning; square protective casing in good condition	Yes	Sep-03	Oct-14	Jul-08	
123	D	50	100	Functioning; round protective casing in good condition	Yes	Oct-05	Oct-14	--	
124	S	50	100	Functioning; square protective casing in good condition	Yes	Jan-12	Oct-14	Jan-12	
125	S	50	100	Functioning; square protective casing in good condition	Yes	Jan-12	Oct-14	Jan-12	
126	S	50	100	Functioning; square protective casing in good condition	Yes	Jan-12	Oct-14	Jan-12	
127	S	50	100	Functioning; square protective casing in good condition	Yes	Jan-12	Oct-14	Jan-12	
128	S	50	100	Functioning; square protective casing in good condition	Yes	Jan-12	Oct-14	Jan-12	
129	S	50	100	Functioning; square protective casing in good condition	Yes	Jan-12	Oct-14	Jan-12	
130	S	50	100	Functioning; square protective casing in good condition	Yes	Jan-12	Oct-14	--	
130A	S	50	100	Functioning; square protective casing in good condition	No	Jan-12	Oct-14	Jan-12	
131	S	50	100	Functioning; square protective casing in good condition	Yes	Jan-12	Oct-14	Jan-12	
132	S	50	100	Functioning; square protective casing in good condition	Yes	Jan-12	Oct-14	Jan-12	
133	I	50	100	Functioning; square protective casing in good condition	Yes	Jan-12	Oct-14	Jan-12	
134	I	50	100	Functioning; square protective casing in good condition	Yes	Jan-12	Oct-14	Jan-12	
135	I	50	100	Functioning; square protective casing in good condition	Yes	Jan-12	Oct-14	Jan-12	

Hanlon Creek Business Park - Groundwater Monitoring Program

Monitoring Well and Mini-Piezometer Condition Summary - as of December 2014

Mini-Piezometer Number	Type **	Nominal Piezometer Diameter (mm)	Protective Casing Size/Diameter (mm)	Condition of Mini-Piezometer	Waterra Tubing In Place	Monitoring Started	Most Recent Monitoring	Data Logger Installed	Data Logger Removed
1S	SP	20	n/a	Functioning - Steel pipe	No	Dec-06	Oct-14	--	
1D	DP	20	n/a	Functioning - Steel pipe	No	Dec-06	Oct-14	Apr-09	
2S	SP	20	n/a	Functioning - Steel pipe	No	Dec-06	Oct-14	--	
2D	DP	20	n/a	Functioning - Steel pipe	No	Dec-06	Oct-14	Jan-07	
4S	SP	20	n/a	Functioning - Steel pipe	No	Dec-06	Oct-14	--	
4D	DP	20	n/a	Functioning - Steel pipe	No	Dec-06	Oct-14	Apr-09	
7S	SP	20	n/a	Functioning - PVC pipe	No	Dec-06	Oct-14	--	
7D	DP	20	n/a	Functioning - PVC pipe	No	Dec-06	Oct-14	Nov-07	
8S	SP	20	n/a	Functioning - Steel pipe	No	Dec-06	Oct-14	--	
8D	DP	20	n/a	Functioning - Steel pipe	No	Dec-06	Oct-14	Jun-10	
9S	SP	20	n/a	Functioning - Steel pipe	No	Mar-07	Oct-14	--	
9D	DP	20	n/a	Functioning - Steel pipe	No	Mar-07	Oct-14	Mar-07	
10S	SP	20	n/a	Functioning - Steel pipe	No	Jun-10	Oct-14	--	
10D	DP	20	n/a	Functioning - Steel pipe	No	Jun-10	Oct-14	Apr-12	
11S	SP	20	n/a	Functioning - Steel pipe	No	Jun-10	Oct-14	--	
11D	DP	20	n/a	Functioning - Steel pipe	No	Jun-10	Oct-14	Jun-10	
12D	DP	20	n/a	Functioning - Steel pipe	No	Jul-11	Oct-14	Jan-12	
13D	DP	20	n/a	Functioning - Steel pipe	No	Jun-13	Oct-14	Jun-13	
14D	DP	20	n/a	Functioning - Steel pipe	No	Jun-13	Oct-14	Jun-13	

* S=shallow (overburden); I=intermediate (overburden); D=deep (bedrock)
** SP=shallow piezometer (1.0m); DP=deeper piezometer (1.5m)

Appendix B

Groundwater Level Monitoring Data
2003 – 2014

Hanlon Creek Business Park - Groundwater Monitoring Program 2003 - 2014

Monitoring Well Elevation Data

Monitoring Well Number	Northing	Easting	Ground Elevation (m)	Original Top of Protective Casing Elevation (m)	Current Top of Well Elevation (m)	Depth to Top of Screen (m)	Depth to Groundwater (m) Apr 23-25/03	Groundwater Elevation (m) Apr 23-25/03	Depth to Groundwater (m) Jul 7/03	Groundwater Elevation (m) Jul 7/03	Depth to Groundwater (m) Sep 3-9/03	Groundwater Elevation (m) Sep 3-9/03	Depth to Groundwater (m) Oct 8/03	Groundwater Elevation (m) Oct 8/03	Depth to Groundwater (m) Nov 6/03	Groundwater Elevation (m) Nov 6/03	Depth to Groundwater (m) Apr 13/04	Groundwater Elevation (m) Apr 13/04	Depth to Groundwater (m) Nov 8, 11/05	Groundwater Elevation (m) Nov 8, 11/05
001	4815738	563019	324.80	325.81		4.00	0.67	324.13			0.84	323.96	0.89	323.91	0.76	324.04	0.43	324.37	0.98	323.82
002	4815264	563116	327.26	328.21		2.20	1.38	325.88			1.87	325.39	damaged	damaged	n/a	n/a	n/a	n/a	n/a	n/a
003	4814814	562436	326.61	327.91	327.784	2.10	0.79	325.82			1.00	325.61	0.96	325.65	0.62	325.99	0.05	326.56	1.01	325.60
004	4814286	562532	330.43	331.33	331.220	5.10	4.44	325.99			4.71	325.72	4.82	325.61	4.75	325.68	3.18	327.25	4.86	325.57
005 (S)	4814708	564015	336.53	337.22		3.00	6.17	330.36			6.74	329.78	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
005 (I)	4814708	564015	336.53	337.22		10.80	9.58	326.95			9.60	326.92	9.66	326.86	9.67	326.86	8.33	328.19	n/a	n/a
006	4815051	563955	334.70	335.70		7.50	7.58	327.12			7.73	326.97	7.74	326.96	7.70	327.00	6.54	328.16	7.61	327.09
101	4816126	562590	321.70	322.55		4.00			4.05	317.65	4.12	317.58	3.96	317.74	3.52	318.18	3.46	318.24	4.26	317.44
102	4815860	562163	320.66	321.56		3.00			1.57	319.10	1.75	318.91	1.41	319.26	0.84	319.83	0.92	319.75	2.26	318.40
103	4815933	562895	323.85	324.86	324.762	2.20			1.14	322.71	1.22	322.63	1.05	322.81	0.65	323.21	0.40	323.45	1.29	322.56
104	4815648	562401	322.04	322.72	322.609	2.30			1.24	320.80	1.21	320.83	0.86	321.18	0.53	321.51	0.63	321.41	1.07	320.97
105	4815489	562700	323.87	324.75	324.610	2.70			1.25	322.62	1.27	322.60	1.12	322.75	1.03	322.84	1.03	322.84	1.12	322.75
106	4815478	563458	328.65	329.53		4.00			2.73	325.92	2.86	325.78	2.77	325.88	2.42	326.23	2.00	326.64	2.75	325.90
107	4815143	563540	327.44	328.15	327.971	1.90			0.98	326.46	1.13	326.31	1.07	326.37	0.80	326.63	0.07	327.37	1.07	326.37
108	4814607	562867	330.33	331.02		5.00			4.11	326.22	4.27	326.06	4.30	326.03	4.12	326.21	3.06	327.27	damaged	damaged
109	4814444	563116	331.70	332.52	332.391	7.20			5.23	326.46	5.41	326.29	5.48	326.22	5.39	326.31	4.09	327.61	5.41	326.29
110	4814502	563532	339.59	340.49		14.80			12.89	326.70	13.06	326.53	13.14	326.44	13.12	326.47	11.74	327.85	12.99	326.60
111	4815365	562710	324.20	324.95	324.900	18.90			n/a	n/a	-0.40	324.60	-0.41	324.61	-0.54	324.74	n/a	n/a	-0.36	324.56
112	4814288	562531	330.44	331.25	331.180	28.00			n/a	n/a	4.97	325.47	5.11	325.33	4.95	325.49	3.64	326.79	5.15	325.29
113	4814478	563532	339.85	340.71		40.80			n/a	n/a	14.43	325.42	14.48	325.37	14.40	325.45	13.33	326.51	14.38	325.47
114	4814640	564115	338.68	339.62		34.10			n/a	n/a	12.86	325.82	12.94	325.74	12.90	325.79	11.72	326.96	12.85	325.83
115	4815311	562313	323.12	323.89	323.760	7.10			n/a	n/a	0.11	323.02	0.03	323.10	-0.02	323.14	0.19	322.93	0.46	322.66
115A	4815309	562312	323.10	323.91	323.770	1.60			0.64	322.45	0.66	322.44	0.29	322.81	0.16	322.93	0.16	322.93	0.26	322.84
116	4816139	562305	318.75	319.68	319.598	9.80			3.83	314.91	3.89	314.86	3.69	315.06	3.21	315.54	2.97	315.78	4.03	314.71
116A	4816139	562311	318.67	319.56	319.478	1.50			0.51	318.16	0.74	317.92	n/a	n/a	0.15	318.52	0.15	318.52	0.63	318.04
117	4815889	562525	321.21	321.94	321.826	7.10			3.07	318.14	3.11	318.09	2.96	318.24	2.63	318.58	2.70	318.51	3.34	317.87
117A	4815885	562527	321.25	322.18	322.076	2.00			1.30	319.95	1.28	319.97	1.21	320.04	0.98	320.26	1.05	320.20	1.25	320.00
118	4815685	562921	324.02	324.91	324.766	7.30			0.59	323.43	0.84	323.18	0.73	323.30	0.45	323.58	0.57	323.45	0.88	323.14
118A	4815689	562926	323.97	324.89	324.611	2.10			0.72	323.25	0.81	323.16	0.69	323.28	0.55	323.41	0.47	323.50	0.77	323.20
119	4815279	562960	325.88	326.93	326.863	6.00			1.16	324.72	1.12	324.76	0.86	325.02	0.62	325.26	0.65	325.24	0.92	324.96
119A	4815280	562965	325.88	326.99	326.918	2.80			1.11	324.77	1.11	324.77	0.85	325.03	0.61	325.27	0.64	325.25	0.92	324.96
120	4814948	563249	327.38	328.89		7.20			0.35	327.04	0.47	326.91	0.36	327.02	0.09	327.29	-0.19	327.57	destroyed	destroyed
120A	4814941	563244	327.38	328.23		2.50			1.06	326.33	1.19	326.19	1.08	326.30	0.80	326.59	0.52	326.87	destroyed	destroyed
121	4814817	563395	327.44	328.15	328.022	8.80			1.55	325.89	1.72	325.72	1.74	325.71	1.58	325.86	0.83	326.61	1.61	325.83
121A	4814817	563396	328.09	328.93	328.885	2.70			1.47	326.61	1.64	326.44	1.67	326.42	1.52	326.57	0.78	327.30	damaged	damaged
122	4814929	562960	326.79	327.64	327.504	5.80			n/a	n/a	0.87	325.93	0.81	325.98	0.69	326.11	0.48	326.31	0.90	325.89
122A	4814931	562959	326.81	327.58	327.514	2.80			n/a	n/a	1.01	325.81	0.96	325.86	0.85	325.97	0.68	326.13	0.78	326.03
123	4815368	562710	324.20	325.06	324.827	49.00			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	14.21	309.99
124	4815650	562155	321.59	322.57	322.410	4.62														
125	4816227	561991	319.23	320.29	320.190	4.16														
126	4816259	562328	320.63	321.49	321.390	4.62														
127	4816149	562485	320.06	321.03	320.930	2.49														
128	4816388	562714	322.22	322.97	323.050	4.62														
129	4815475	563115	326.16	327.12	327.060	4.62														
130	4815757	562823	323.55	324.54	324.500	1.99														
130A	4815764	562819	323.58	323.52	324.530	0.89														
131	4815181	563267	326.72	327.65	327.540	3.07														
132	4815128	564031	334.98	335.90	335.780	7.36														
133	4814714	564395	340.08	341.09	340.940	12.54														
134	4814454	563436	341.46	342.11	341.960	14.83														
135	4814765	563819	333.54	334.66	334.360	9.19														

Hanlon Creek Business Park - Groundwater Monitoring Program 2003 - 2014

Monitoring Well Elevation Data

Monitoring Well Number	Depth to Groundwater (m) Apr 26/06	Groundwater Elevation (m) Apr 26/06	Depth to Groundwater (m) Dec 20/06	Groundwater Elevation (m) Dec 20/06	Depth to Groundwater (m) Feb 1/07	Groundwater Elevation (m) Feb 1/07	Depth to Groundwater (m) Apr 27/07	Groundwater Elevation (m) Apr 27/07	Depth to Groundwater (m) Jul 25/07	Groundwater Elevation (m) Jul 25/07	Depth to Groundwater (m) Nov 2/07	Groundwater Elevation (m) Nov 2/07	Depth to Groundwater (m) Jan 25,29/08	Groundwater Elevation (m) Jan 25,29/08	Depth to Groundwater (m) Apr 22-25/08	Groundwater Elevation (m) Apr 22-25/08	Depth to Groundwater (m) Jul 23-28/08	Groundwater Elevation (m) Jul 23-28/08	Depth to Groundwater (m) Oct 24-28/08	Groundwater Elevation (m) Oct 24-28/08
001	0.54	324.27	0.47	324.33	0.56	324.24	0.47	324.33	0.93	323.87	1.13	323.67	0.51	324.29	0.38	324.42	0.59	324.22	0.77	324.034
002	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.93	325.33	1.99	325.27	1.31	325.95	1.25	326.01	1.35	325.91	1.43	325.83
003	0.13	326.48	0.24	326.37	0.28	326.33	0.04	326.57	0.72	325.89	1.13	325.48	0.44	326.17	0.03	326.58	0.39	326.22	0.69	325.924
004	3.68	326.75	3.87	326.56	3.78	326.65	3.40	327.03	4.24	326.19	4.91	325.52	4.21	326.22	2.90	327.53	3.94	326.49	4.40	326.03
005 (S)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	moist/dry	moist/dry	dry	dry	6.43	330.10	6.33	330.20	6.20	330.33	6.47	330.05
005 (I)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	8.65	327.88	9.37	327.16	9.24	327.29	7.91	328.62	8.40	328.13	8.83	327.70
006	6.83	327.88	6.94	327.77	6.85	327.85	6.43	328.27	6.96	327.74	7.59	327.11	7.24	327.46	6.16	328.54	6.65	328.05	7.08	327.62
101	3.70	318.00	3.61	318.09	3.86	317.84	3.69	318.01	4.16	317.54	4.35	317.35	3.61	318.09	3.21	318.49	3.91	317.79	3.93	317.77
102	0.95	319.71	0.98	319.68	1.08	319.58	0.92	319.74	1.94	318.72	2.36	318.30	0.92	319.74	0.77	319.89	0.48	320.18	1.51	319.15
103	0.56	323.29	0.53	323.32	0.76	323.09	0.52	323.33	1.41	322.44	1.45	322.40	0.52	323.33	0.41	323.44	0.80	323.05	1.06	322.79
104	0.53	321.51	0.68	321.36	0.79	321.25	0.55	321.49	1.45	320.59	1.34	320.70	0.58	321.46	0.61	321.43	0.74	321.30	0.90	321.139
105	1.02	322.85	1.07	322.80	1.11	322.76	0.94	322.93	1.39	322.48	1.25	322.62	1.10	322.77	1.05	322.82	1.10	322.77	1.15	322.717
106	2.17	326.47	2.16	326.48	2.23	326.42	1.99	326.66	2.58	326.07	2.89	325.76	2.26	326.39	1.82	326.83	2.15	326.50	2.46	326.19
107	0.39	327.05	0.45	326.99	0.48	326.96	n/a	n/a	0.73	326.71	1.15	326.29	0.66	326.78	-0.08	327.52	0.29	327.145	0.69	326.745
108	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
109	4.46	327.24	4.67	327.03	4.52	327.18	4.14	327.56	4.82	326.88	5.41	326.29	4.99	326.71	3.79	327.91	4.60	327.10	4.96	326.74
110	12.07	327.52	12.31	327.28	12.11	327.48	11.69	327.90	12.29	327.30	12.96	326.63	12.70	326.89	11.39	328.20	12.06	327.53	12.45	327.14
111	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-0.83	325.03	-0.47	324.67	-0.98	325.18	-1.73	325.93	-0.85	325.05	-0.66	324.86
112	3.82	326.62	4.22	326.22	4.19	326.25	3.95	326.49	4.67	325.77	5.09	325.35	4.47	325.97	3.37	327.07	4.18	326.26	4.63	325.81
113	13.65	326.20	13.66	326.19	13.53	326.32	13.12	326.73	13.75	326.10	14.30	325.55	13.96	325.89	12.90	326.95	13.59	326.26	13.97	325.88
114	12.09	326.59	12.20	326.48	11.96	326.72	11.64	327.04	12.03	326.65	12.64	326.04	12.39	326.29	11.25	327.43	11.81	326.87	12.23	326.45
115	0.15	322.97	frozen	frozen	frozen	frozen	0.36	322.77	-0.02	323.14	-0.07	323.19	frozen	frozen	-0.64	323.76	-0.64	323.76	-0.32	323.45
115A	0.11	322.99	0.19	322.90	0.19	322.90	0.05	323.05	1.12	321.97	0.75	322.34	0.28	322.81	0.27	322.82	-0.01	323.10	0.35	322.74
116	3.02	315.73	3.07	315.68	3.35	315.39	3.03	315.71	4.12	314.63	4.34	314.41	3.40	315.35	2.75	316.00	4.12	314.63	3.91	314.84
116A	0.17	318.50	0.26	318.41	0.32	318.35	0.16	318.50	1.09	317.58	1.11	317.56	0.20	318.47	0.18	318.49	0.40	318.27	0.46	318.208
117	2.88	318.33	2.91	318.30	3.03	318.17	3.02	318.19	3.16	318.05	3.17	318.04	2.66	318.55	2.37	318.84	3.15	318.06	2.96	318.25
117A	1.01	320.24	1.06	320.19	1.17	320.08	0.79	320.45	1.42	319.83	1.32	319.93	1.12	320.13	1.00	320.25	1.21	320.04	1.15	320.099
118	0.67	323.35	0.60	323.42	0.73	323.29	0.59	323.43	0.69	323.33	0.68	323.34	0.36	323.66	0.27	323.75	0.53	323.49	0.59	323.43
118A	0.60	323.37	0.64	323.33	0.69	323.28	0.52	323.45	0.98	322.99	0.93	323.04	0.66	323.31	0.64	323.33	0.71	323.26	0.76	323.204
119	0.58	325.30	0.63	325.25	0.66	325.22	0.51	325.37	1.16	324.72	1.03	324.85	0.73	325.15	0.66	325.22	0.53	325.35	0.70	325.18
119A	0.58	325.30	0.62	325.26	0.65	325.23	0.70	325.19	1.15	324.73	1.01	324.87	0.71	325.17	0.64	325.24	0.53	325.35	0.69	325.196
120	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
120A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
121	0.95	326.49	1.06	326.38	0.94	326.51	1.06	326.38	1.09	326.35	1.63	325.81	1.29	326.15	0.73	326.71	0.94	326.50	1.15	326.29
121A	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.10	326.99	1.63	326.46	1.51	326.58	0.79	327.30	0.96	327.13	1.15	326.935
122	0.55	326.24	0.60	326.19	0.59	326.20	0.49	326.30	0.72	326.07	0.83	325.96	0.65	326.14	0.49	326.30	0.49	326.30	0.66	326.13
122A	0.75	326.06	0.71	326.10	0.79	326.03	0.72	326.10	0.88	325.93	0.97	325.84	0.83	325.98	0.69	326.12	0.69	326.12	0.82	325.991
123	17.53	306.67	n/a	n/a	n/a	n/a	18.26	305.94	18.95	305.25	19.54	304.66	13.56	310.64	12.45	311.75	15.98	308.22	17.12	307.08
124																				
125																				
126																				
127																				
128																				
129																				
130																				
130A																				
131																				
132																				
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134																				
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Hanlon Creek Business Park - Groundwater Monitoring Program 2003 - 2014

Monitoring Well Elevation Data

Monitoring Well Number	Depth to Groundwater (m) Jan 2, 3/09	Groundwater Elevation (m) Jan 2, 3/09	Depth to Groundwater (m) Apr 27-29/09	Groundwater Elevation (m) Apr 27-29/09	Depth to Groundwater (m) May 20/09	Groundwater Elevation (m) May 20/09	Depth to Groundwater (m) Jul 29/09	Groundwater Elevation (m) Jul 29/09	Depth to Groundwater (m) Aug 27/09	Groundwater Elevation (m) Aug 27/09	Depth to Groundwater (m) Oct 26, 27/09	Groundwater Elevation (m) Oct 26, 27/09
001	0.40	324.404	0.37	324.434	0.46	324.339	0.60	324.201			0.70	324.099
002	n/a	n/a	n/a	n/a			n/a	n/a			n/a	n/a
003	0.05	326.561	-0.03	326.644			0.31	326.304			0.60	326.014
004	3.56	326.87	3.14	327.29			3.89	326.54	4.04	326.390	4.35	326.075
005 (S)	6.01	330.52	6.42	330.11			6.46	330.07	6.45	330.08	dry	dry
005 (I)	8.71	327.82	7.71	328.82			8.15	328.38	8.29	328.239	8.67	327.854
006	6.71	327.99	6.04	328.66			6.49	328.21	6.58	328.122	6.95	327.757
101	3.05	318.65	3.18	318.52					4.08	317.62	3.82	317.88
102	0.53	320.13	0.53	320.13					1.49	319.17	1.32	319.34
103	0.30	323.55	0.34	323.51					0.95	322.90	1.05	322.80
104	0.49	321.549	0.43	321.609	0.71	321.329			0.90	321.139	0.87	321.174
105	1.03	322.835	0.94	322.930	1.07	322.795	1.08	322.785			1.08	322.788
106	1.88	326.77	1.72	326.93			2.17	326.48	2.20	326.447	2.37	326.277
107	0.19	327.245	-0.32	327.760			0.30	327.140			0.59	326.850
108	-	-	-	-			-	-			-	-
109	4.39	327.31	3.83	327.871			4.49	327.211			4.87	326.831
110	12.16	327.43	11.36	328.23			11.89	327.70	12.04	327.546	12.34	327.251
111	-0.85	325.05	nm				-1.02	325.22			-0.53	324.73
112	3.90	326.54	3.65	326.79			4.20	326.24			4.89	325.55
113	13.68	326.17	12.98	326.87			13.43	326.42			14.01	325.84
114	12.00	326.68	11.25	327.43			11.61	327.07			12.19	326.49
115	frozen	frozen	-0.64	323.76					-0.43	323.55	-0.38	323.50
115A	0.17	322.92	0.00	323.09					0.36	322.73	0.18	322.91
116	not available	not available	2.80	315.95	3.17	315.58			4.49	314.26	3.70	315.05
116A	0.10	318.568	0.14	318.528	0.32	318.348			0.40	318.268	0.48	318.183
117	2.36	318.85	2.42	318.79	2.68	318.53			3.39	317.82	2.88	318.33
117A	0.88	320.366	0.89	320.356	1.09	320.156			1.25	319.996	1.16	320.091
118	0.33	323.69	0.28	323.74	0.43	323.59	0.48	323.54			0.54	323.48
118A	0.49	323.481	0.47	323.501	0.81	323.156	0.67	323.298			0.72	323.251
119	0.61	325.27	0.46	325.42	0.66	325.22	0.63	325.25			0.64	325.24
119A	0.60	325.285	0.46	325.418	0.64	325.243	0.61	325.268			0.62	325.258
120	-	-	-	-	-	-	-	-	-	-	-	-
120A	-	-	-	-	-	-	-	-	-	-	-	-
121	0.91	326.53	0.70	326.74			0.87	326.57			1.06	326.38
121A	0.94	327.145	0.75	327.335			0.90	327.190			1.08	327.010
122	0.51	326.28	0.41	326.38	0.49	326.30	0.53	326.26			0.60	326.19
122A	0.71	326.109	0.64	326.174	0.70	326.114	0.73	326.084			0.79	326.029
123	16.99	307.21	16.87	307.33							17.14	307.06
124												
125												
126												
127												
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129												
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130A												
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Hanlon Creek Business Park - Groundwater Monitoring Program 2003 - 2014

Monitoring Well Elevation Data

Monitoring Well Number	Depth to Groundwater (m) Jan 28, 29/10	Groundwater Elevation (m) Jan 28, 29/10	Depth to Groundwater (m) Apr 26-28/10	Groundwater Elevation (m) Apr 26-28/10	Depth to Groundwater (m) Jul 22, 23/10	Groundwater Elevation (m) Jul 22, 23/10	Depth to Groundwater (m) Sep 19/10	Groundwater Elevation (m) Sep 19/10	Depth to Groundwater (m) Oct 12-14/10	Groundwater Elevation (m) Oct 12-14/10
001	0.64	324.164	0.58	324.219	0.91	323.894			0.95	323.854
002	n/a	n/a	n/a	n/a	n/a	n/a			abandoned	abandoned
003	0.51	326.099	0.26	326.349	0.70	325.909			0.97	325.644
004	4.33	326.100	3.76	326.665	4.29	326.140			4.73	325.700
005 (S)	dry	dry	6.43	330.09	dry	dry	dry	dry	abandoned	abandoned
005 (I)	9.02	327.504	8.63	327.894	8.90	327.629	9.15	327.374	abandoned	abandoned
006	7.19	327.512	6.87	327.837	7.15	327.557	7.39	327.317	abandoned	abandoned
101	3.78	317.92	3.63	318.07	3.98	317.720			4.04	317.660
102	0.68	319.98	0.94	319.72	abandoned	abandoned			-	-
103	0.95	322.90	0.74	323.11	1.28	322.572			1.33	322.517
104	0.76	321.279	0.80	321.239	1.17	320.869			1.22	320.819
105	1.06	322.810	1.11	322.760	1.34	322.525			1.21	322.655
106	2.36	326.287	2.24	326.407	2.56	326.082			abandoned	abandoned
107	0.66	326.780	0.48	326.955	0.83	326.606			0.87	326.561
108	-	-	-	-	-	-			-	-
109	4.96	326.741	4.52	327.176	4.94	326.761			5.28	326.421
110	12.55	327.036	12.12	327.466	12.44	327.151	12.74	326.851	abandoned	abandoned
111	-0.58	324.78	-0.74	324.94	-0.46	324.66			-0.33	324.53
112	4.87	325.57	4.47	325.97	4.80	325.64			5.13	325.31
113	14.14	325.71	13.79	326.06	14.11	325.74	14.30	325.55	abandoned	abandoned
114	12.40	326.28	12.04	326.64	12.39	326.29	12.58	326.11	abandoned	abandoned
115	-0.49	323.61	-0.50	323.62	-0.06	323.19			-0.21	323.33
115A	0.14	322.95	0.15	322.94	0.69	322.40			0.37	322.72
116	3.58	315.17	3.43	315.32	3.95	314.80			4.02	314.73
116A	0.40	318.268	0.39	318.278	0.92	317.743			0.78	317.888
117	2.83	318.38	2.81	318.40	3.39	317.82			2.93	318.28
117A	1.12	320.131	1.15	320.096	1.93	319.316			0.99	320.261
118	0.50	323.52	0.52	323.50	0.58	323.44			0.56	323.46
118A	0.68	323.291	0.71	323.261	0.92	323.051			0.87	323.101
119	0.62	325.26	0.69	325.19	0.65	325.23			0.84	325.04
119A	0.61	325.268	0.68	325.198	0.62	325.258			0.82	325.058
120	-	-	-	-	-	-			abandoned	abandoned
120A	-	-	-	-	-	-			abandoned	abandoned
121	1.18	326.26	0.95	326.49	1.23	326.22			1.42	326.03
121A	1.19	326.895	0.98	327.110	1.23	326.855			1.43	326.655
122	0.65	326.14	0.59	326.20	0.50	326.29			0.76	326.03
122A	0.84	325.979	0.79	326.029	0.70	326.119			0.92	325.899
123	18.59	305.50	18.41	305.68	19.13	304.96			19.29	304.80
124										
125										
126										
127										
128										
129										
130										
130A										
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Hanlon Creek Business Park - Groundwater Monitoring Program 2003 - 2014

Monitoring Well Elevation Data

Monitoring Well Number	Depth to Groundwater (m) Jan 18, 19/11	Groundwater Elevation (m) Jan 18, 19/11	Depth to Groundwater (m) Apr 27, 28/11	Groundwater Elevation (m) Apr 27, 28/11	Depth to Groundwater (m) Jul 18, 19/11	Groundwater Elevation (m) Jul 18, 19/11	Depth to Groundwater (m) Oct 20, 25/11	Groundwater Elevation (m) Oct 20, 25/11	Depth to Groundwater (m) Jan 10-18/12	Groundwater Elevation (m) Jan 10-18/12	Depth to Groundwater (m) Apr 13, 16/12	Groundwater Elevation (m) Apr 13, 16/12	Depth to Groundwater (m) Jul 16, 19/12	Groundwater Elevation (m) Jul 16, 19/12	Depth to Groundwater (m) Oct 16, 18/12	Groundwater Elevation (m) Oct 16, 18/12
001	1.07	323.734	0.57	324.239	abandoned	abandoned	-	-	-	-	-	-	-	-	-	-
002	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
003	0.93	325.679	0.00	326.609	0.37	326.239	0.64	325.969	0.26	326.349	0.46	326.154	1.04	325.569	1.31	325.304
004	4.76	325.670	3.63	326.795	3.65	326.775	4.55	325.880	3.99	326.440	4.03	326.400	4.67	325.755	5.11	325.320
005 (S)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
005 (I)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
006	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
101	4.06	317.640	abandoned	abandoned	-	-	-	-	-	-	-	-	-	-	-	-
102	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
103	1.35	322.497	0.58	323.272	1.44	322.412	1.23	322.622	0.94	322.912	1.26	322.592	1.75	322.102	1.44	322.417
104	1.12	320.924	0.62	321.419	0.94	321.099	0.76	321.284	0.74	321.299	0.98	321.059	1.42	320.624	1.17	320.869
105	1.23	322.635	0.98	322.895	1.25	322.620	0.83	323.040	1.09	322.780	1.18	322.690	1.54	322.330	1.21	322.665
106	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
107	1.30	326.136	0.44	326.996	0.77	326.666	1.22	326.216	1.02	326.416	1.11	326.321	1.37	326.061	1.46	325.976
108	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
109	5.36	326.341	4.45	327.251	4.35	327.351	5.05	326.651	4.77	326.931	4.76	326.941	5.29	326.406	5.64	326.061
110	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
111	-0.27	324.470	-0.95	325.145	-0.81	325.005	-0.50	324.700	-0.70	324.900	-0.70	324.900	-0.22	324.415	-0.20	324.400
112	5.15	325.29	4.09	326.350	4.26	326.175	4.88	325.560	4.33	326.105	4.48	325.960	5.21	325.230	5.32	325.120
113	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
114	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
115	-0.36	323.48	-0.63	323.75	-0.16	323.28	-0.45	323.57	-0.49	323.61	-0.46	323.58	0.29	322.83	-0.09	323.21
115A	0.29	322.80	0.02	323.07	0.82	322.28	0.00	323.10	0.15	322.95	0.18	322.92	1.16	321.94	0.45	322.65
116	3.98	314.77	2.96	315.79	3.51	315.24	3.52	315.23	3.19	315.56	3.65	315.10	4.20	314.55	3.98	314.77
116A	0.75	317.918	0.28	318.388	0.57	318.098	0.20	318.468	0.33	318.338	0.53	318.138	1.16	317.508	0.70	317.973
117	2.92	318.29	2.40	318.81	2.90	318.31	2.62	318.59	2.67	318.54	2.94	318.27	3.22	317.99	2.94	318.27
117A	0.96	320.286	0.67	320.581	1.17	320.076	0.55	320.696	1.02	320.226	1.14	320.111	1.28	319.966	1.07	320.176
118	0.61	323.41	0.30	323.73	0.82	323.21	0.56	323.47	0.46	323.56	0.59	323.43	1.00	323.02	0.63	323.40
118A	0.93	323.041	0.64	323.336	1.17	322.806	0.76	323.211	0.78	323.191	0.92	323.051	1.29	322.686	0.93	323.041
119	0.58	325.30	0.21	325.68	2.12	323.76	0.76	325.12	0.89	324.99	0.97	324.91	1.04	324.84	1.01	324.88
119A	0.58	325.303	0.20	325.683	2.12	323.768	0.73	325.153	0.87	325.018	0.95	324.938	1.03	324.858	0.98	324.903
120	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
120A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
121	1.64	325.81	0.95	326.49	0.84	326.61	1.21	326.24	1.22	326.22	1.21	326.24	1.62	325.82	1.87	325.57
121A	1.65	326.440	0.97	327.115	0.89	327.200	1.22	326.870	1.22	326.865	1.20	326.885	1.63	326.460	1.89	326.195
122	0.80	325.99	0.49	326.31	0.79	326.00	0.62	326.17	0.62	326.17	0.66	326.13	0.88	325.91	0.96	325.83
122A	0.95	325.864	0.70	326.114	0.78	326.039	0.80	326.019	0.81	326.009	0.84	325.974	1.03	325.789	1.09	325.724
123	19.33	304.76	17.55	306.54	17.28	306.81	15.80	308.29	15.77	308.32	11.18	312.91	18.48	305.61	16.73	307.36
124									1.30	320.29	1.76	319.83	2.39	319.20	2.31	319.28
125									4.40	314.83	4.83	314.40	5.20	314.03	5.01	314.22
126									3.28	317.35	3.81	316.82	5.01	315.62	4.61	316.02
127									1.51	318.55	1.67	318.39	1.87	318.20	1.66	318.40
128									1.93	320.29	2.03	320.20	2.28	319.94	2.12	320.10
129									1.10	325.07	1.29	324.87	1.54	324.62	1.25	324.91
130									1.03	322.52	n/a	n/a	1.56	321.99	1.08	322.47
130A									0.94	322.65	n/a	n/a	1.44	322.14	1.03	322.56
131									1.33	325.39	1.40	325.33	1.19	325.53	1.04	325.68
132									7.25	327.73	7.31	327.68	7.61	327.38	7.82	327.16
133									12.05	328.03	11.97	328.11	12.35	327.73	12.68	327.40
134									14.40	327.06	14.30	327.16	14.83	326.63	15.19	326.27
135									6.34	327.20	6.30	327.24	6.69	326.85	6.99	326.55

Hanlon Creek Business Park - Groundwater Monitoring Program 2003 - 2014

Monitoring Well Elevation Data

Monitoring Well Number	Depth to Groundwater (m) Jan 10, 11/13	Groundwater Elevation (m) Jan 10, 11/13	Depth to Groundwater (m) Apr 25, 26/13	Groundwater Elevation (m) Apr 25, 26/13	Depth to Groundwater (m) Jul 15, 16/13	Groundwater Elevation (m) Jul 15, 16/13	Depth to Groundwater (m) Oct 23, 24/13	Groundwater Elevation (m) Oct 23, 24/13	Depth to Groundwater (m) Jan 13, 14/14	Groundwater Elevation (m) Jan 13, 14/14	Depth to Groundwater (m) Apr 22, 23/14	Groundwater Elevation (m) Apr 22, 23/14	Depth to Groundwater (m) Jul 14, 15/14	Groundwater Elevation (m) Jul 14, 15/14	Depth to Groundwater (m) Oct 9, 10/14	Groundwater Elevation (m) Oct 9, 10/14
001	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
002	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
003	0.88	325.729	0.05	326.564	0.46	326.154	0.59	326.024	0.21	326.404	0.05	326.559	0.47	326.144	0.58	326.034
004	4.74	325.690	3.27	327.160	3.93	326.495	4.47	325.960	4.17	326.260	3.30	327.130	3.94	326.490	4.32	326.110
005 (S)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
005 (I)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
006	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
101	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
102	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
103	1.18	322.672	0.64	323.212	1.09	322.767	0.97	322.887	0.95	322.902	0.66	323.192	1.35	322.502	0.98	322.872
104	0.73	321.309	0.54	321.499	0.86	321.179	0.71	321.329	0.57	321.469	0.65	321.389	1.07	320.969	0.79	321.249
105	1.13	322.745	1.02	322.850	1.25	322.620	1.06	322.815	1.01	322.860	1.06	322.810	1.29	322.580	1.11	322.765
106	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
107	1.37	326.066	0.77	326.661	0.84	326.591	0.99	326.446	1.00	326.431	0.75	326.681	0.89	326.541	0.94	326.491
108	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
109	5.40	326.301	4.20	327.501	4.63	327.066	5.01	326.691	4.88	326.821	4.19	327.511	4.62	327.081	4.92	326.781
110	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
111	-0.46	324.660	-1.19	325.390	-0.97	325.174	-0.82	325.020	frozen	frozen	-1.07	325.273	-0.83	325.030	-0.75	324.950
112	4.96	325.480	3.67	326.770	4.26	326.180	4.68	325.760	4.37	326.070	3.65	326.790	4.31	326.130	4.56	325.880
113	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
114	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
115	-0.34	323.46	-0.64	323.76	-0.39	323.51	-0.50	323.62	-0.59	323.71	-0.64	323.76	-0.35	323.47	-0.53	323.65
115A	0.15	322.95	0.11	322.99	0.48	322.62	0.13	322.97	0.06	323.03	0.10	323.00	0.55	322.55	0.17	322.93
116	3.61	315.14	2.88	315.87	3.27	315.48	2.80	315.95	3.22	315.53	2.79	315.96	3.52	315.23	3.18	315.57
116A	0.45	318.218	0.28	318.393	0.52	318.153	0.37	318.298	0.24	318.428	0.31	318.358	0.71	317.958	0.45	318.218
117	2.82	318.39	2.54	318.67	2.78	318.43	2.51	318.70	2.58	318.63	2.52	318.69	2.92	318.29	2.68	318.53
117A	1.07	320.176	1.00	320.246	1.17	320.081	1.03	320.221	0.96	320.286	1.03	320.216	1.19	320.056	1.11	320.136
118	0.57	323.46	0.36	323.67	0.51	323.52	0.43	323.60	0.39	323.64	0.39	323.64	0.75	323.28	0.59	323.44
118A	0.86	323.111	0.72	323.251	0.88	323.091	0.76	323.211	0.73	323.241	0.76	323.211	0.97	323.001	0.79	323.181
119	1.00	324.88	0.91	324.97	0.99	324.90	0.92	324.96	0.80	325.08	0.90	324.98	1.01	324.87	0.96	324.92
119A	0.98	324.908	0.89	324.993	0.97	324.918	0.90	324.988	0.79	325.098	0.88	325.008	1.00	324.888	0.95	324.938
120	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
120A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
121	1.72	325.72	0.95	326.49	1.03	326.41	1.24	326.20	1.18	326.26	0.93	326.52	1.03	326.41	1.18	326.26
121A	1.73	326.355	0.98	327.110	1.05	327.035	1.25	326.835	1.20	326.890	0.95	327.135	1.04	327.045	1.18	326.905
122	0.78	326.01	0.50	326.29	0.64	326.15	0.64	326.15	0.54	326.25	0.50	326.29	0.64	326.15	0.65	326.14
122A	0.93	325.884	0.71	326.104	0.83	325.984	0.82	325.994	0.75	326.064	0.73	326.084	0.83	325.984	0.83	325.984
123	16.25	307.84	15.46	308.63	17.41	306.68	17.27	306.82	17.11	306.98	16.27	307.82	17.06	307.03	17.09	307.00
124	1.40	320.20	1.17	320.42	1.64	319.96	1.25	320.34	1.16	320.43	1.20	320.39	2.03	319.56	1.36	320.23
125	4.79	314.44	4.06	315.18	4.54	314.69	4.16	315.08	4.47	314.76	3.96	315.28	4.70	314.53	4.51	314.72
126	3.79	316.85	2.99	317.64	2.74	317.89	2.54	318.10	2.66	317.98	2.48	318.16	3.13	317.51	2.59	318.04
127	1.57	318.49	1.41	318.66	1.56	318.50	1.46	318.61	1.42	318.64	1.39	318.68	1.61	318.46	1.48	318.58
128	2.01	320.21	1.80	320.43	1.90	320.32	1.87	320.36	1.82	320.40	1.83	320.40	1.99	320.23	1.87	320.35
129	1.19	324.97	0.92	325.24	1.12	325.04	1.00	325.16	0.93	325.23	0.91	325.25	1.20	324.96	1.05	325.11
130	1.11	322.44	1.05	322.50	1.18	322.37	1.06	322.50	1.01	322.54	1.05	322.51	1.25	322.30	1.07	322.48
130A	1.01	322.58	0.84	322.75	1.05	322.53	0.91	322.67	0.86	322.73	0.89	322.69	1.13	322.45	0.93	322.65
131	0.98	325.74	0.66	326.06	0.80	325.93	0.75	325.97	0.62	326.10	0.66	326.06	0.81	325.91	0.80	325.92
132	7.82	327.16	7.05	327.93	6.96	328.02	7.26	327.72	7.36	327.62	7.01	327.97	6.97	328.01	7.09	327.89
133	12.76	327.33	11.86	328.22	11.58	328.50	11.96	328.12	12.12	327.96	11.76	328.32	11.54	328.54	11.80	328.28
134	15.04	326.43	13.89	327.57	14.15	327.31	14.55	326.91	14.50	326.96	13.85	327.61	14.11	327.35	14.43	327.03
135	6.94	326.60	6.05	327.49	6.02	327.53	6.37	327.17	6.43	327.11	6.00	327.54	6.00	327.54	6.24	327.30

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Piezometer Groundwater Elevation Data

Piezometer Number	Type	Approximate Ground Elevation (mamsl)	Depth to Groundwater (m) Dec 20/06	Groundwater Elevation (m) Dec 20/06	Depth to Groundwater (m) Jan 23/07	Groundwater Elevation (m) Jan 23/07	Depth to Groundwater (m) Apr 27/07	Groundwater Elevation (m) Apr 27/07	Depth to Groundwater (m) May 28/07	Groundwater Elevation (m) May 28/07
PZ-1	S	327.40	0.80	326.60	frozen	frozen	-0.09	327.49		
PZ-1	D	327.40	0.13	327.27	0.20	327.20	flowing	flowing		
PZ-2	S	326.20	0.35	325.85	0.12	326.08	-0.04	326.24		
PZ-2	D	326.20	0.96	325.24	0.14	326.06	0.09	326.11		
PZ-4	S	322.30	0.52	321.78	frozen	frozen	0.00	322.30		
PZ-4	D	322.30	-0.09	322.39	frozen	frozen	flowing	flowing		
PZ-7	S	321.40	0.27	321.13	-0.01	321.41	destroyed	destroyed		
PZ-7	D	321.40	0.09	321.31	0.00	321.40	destroyed	destroyed		
PZ-8	S	318.50	-0.03	318.53	-0.02	318.52	-0.10	318.60		
PZ-8	D	318.50	-0.03	318.53	-0.02	318.52	flowing	flowing		
PZ-9	S	326.15	n/a	n/a	n/a	n/a	n/a	n/a	-0.28	326.43
PZ-9	D	326.15	n/a	n/a	n/a	n/a	n/a	n/a	-0.25	326.40
PZ-10	S	318.30								
PZ-10	D	318.30								
PZ-11	S	320.25								
PZ-11	D	320.25								
PZ-12	D	326.50								
PZ-13	D	324.20								
PZ-14	D	324.20								

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Piezometer Groundwater Elevation Data

Piezometer Number	Depth to Groundwater (m) Jul 25, 26/07	Groundwater Elevation (m) July 25, 26/07	Depth to Groundwater (m) Aug 2/07	Groundwater Elevation (m) Aug 2/07	Depth to Groundwater (m) Aug 17/07	Groundwater Elevation (m) Aug 17/07	Depth to Groundwater (m) Oct 1/07	Groundwater Elevation (m) Oct 1/07	Depth to Groundwater (m) Nov 2/07	Groundwater Elevation (m) Nov 2/07
PZ-1	-0.03	327.43							0.34	327.06
PZ-1	0.10	327.30							0.57	326.83
PZ-2	0.56	325.64			0.63	325.57			0.36	325.84
PZ-2	0.47	325.73			0.54	325.66			0.39	325.81
PZ-4	0.20	322.10							0.13	322.17
PZ-4	0.29	322.01							0.12	322.18
PZ-7	installed new	n/a	0.01	321.39			-0.01	321.41	-0.06	321.46
PZ-7	installed new	n/a	0.01	321.39			-0.01	321.41	-0.07	321.47
PZ-8	0.31	318.19							0.38	318.12
PZ-8	0.30	318.20							0.36	318.14
PZ-9	n/a	n/a			dry	dry			dry	dry
PZ-9	n/a	n/a			0.40	325.75			0.66	325.49
PZ-10										
PZ-10										
PZ-11										
PZ-11										
PZ-12										
PZ-13										
PZ-14										

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Piezometer Groundwater Elevation Data

Piezometer Number	Depth to Groundwater (m) Jan 25/08	Groundwater Elevation (m) Jan 25/08	Depth to Groundwater (m) Apr 25/08	Groundwater Elevation (m) Apr 25/08	Depth to Groundwater (m) Jul 23/08	Groundwater Elevation (m) Jul 23/08	Depth to Groundwater (m) Oct 28/08	Groundwater Elevation (m) Oct 28/08
PZ-1	0.26	327.14	-0.03	327.43	-0.10	327.50	0.00	327.40
PZ-1	0.20	327.20	-0.14	327.54	-0.07	327.47	0.10	327.30
PZ-2	0.23	325.97	-0.03	326.23	-0.02	326.22	0.19	326.01
PZ-2	0.21	325.99	0.04	326.16	0.10	326.10	0.21	325.99
PZ-4	frozen	frozen	0.02	322.28	0.02	322.28	0.05	322.25
PZ-4	frozen	frozen	-0.06	322.36	-0.05	322.35	-0.02	322.32
PZ-7	-0.08	321.48	-0.08	321.48	-0.07	321.47	-0.13	321.53
PZ-7	-0.04	321.44	-0.09	321.49	-0.08	321.48	-0.13	321.53
PZ-8	-0.17	318.67	-0.08	318.58	0.05	318.45	0.01	318.49
PZ-8	frozen	frozen	-0.10	318.60	0.05	318.45	0.16	318.34
PZ-9	frozen	frozen	-0.38	326.53	-0.13	326.28	0.19	325.96
PZ-9	frozen	frozen	-0.42	326.57	-0.08	326.23	0.23	325.93
PZ-10								
PZ-10								
PZ-11								
PZ-11								
PZ-12								
PZ-13								
PZ-14								

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Piezometer Groundwater Elevation Data

Piezometer Number	Depth to Groundwater (m) Jan 2, 3/09	Groundwater Elevation (m) Jan 2, 3/09	Depth to Groundwater (m) Apr 13, May 20/09	Groundwater Elevation (m) Apr 13, May 20/09	Depth to Groundwater (m) Jul 29/09	Groundwater Elevation (m) Jul 29/09	Depth to Groundwater (m) Aug 27/09	Groundwater Elevation (m) Aug 27/09	Depth to Groundwater (m) Oct 26, 27/09	Groundwater Elevation (m) Oct 26, 27/09
PZ-1	frozen	n/a	-0.05	327.45	-0.01	327.41			0.05	327.35
PZ-1	frozen	n/a	-0.13	327.53	-0.08	327.48			0.08	327.32
PZ-2	frozen	n/a	-0.03	326.23	0.00	326.20			0.14	326.06
PZ-2	0.05	326.15	0.04	326.16	0.06	326.14			0.14	326.06
PZ-4	frozen	n/a	-0.02	322.32	n/a	n/a	0.04	322.26	0.03	322.27
PZ-4	frozen	n/a	-0.14	322.44	n/a	n/a	0.01	322.29	-0.06	322.36
PZ-7	frozen	n/a	-0.08	321.48	n/a	n/a	-0.06	321.46	-0.11	321.51
PZ-7	-0.13	321.53	-0.09	321.49	n/a	n/a	-0.07	321.47	-0.11	321.51
PZ-8	frozen	n/a	-0.05	318.55	n/a	n/a	0.10	318.40	0.04	318.46
PZ-8	frozen	n/a	-0.07	318.57	n/a	n/a	0.09	318.41	0.03	318.47
PZ-9	frozen	n/a	-0.42	326.57	-0.24	326.39			0.05	326.10
PZ-9	frozen	n/a	-0.47	326.62	-0.16	326.31			0.13	326.03
PZ-10										
PZ-10										
PZ-11										
PZ-11										
PZ-12										
PZ-13										
PZ-14										

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Piezometer Groundwater Elevation Data

Piezometer Number	Depth to Groundwater (m) Jan 28, 29/10	Groundwater Elevation (m) Jan 28, 29/10	Depth to Groundwater (m) Apr 26-28/10	Groundwater Elevation (m) Apr 26-28/10	Depth to Groundwater (m) Jun 16/10	Groundwater Elevation (m) Jun 16/10	Depth to Groundwater (m) Jul 22/10	Groundwater Elevation (m) Jul 22/10	Depth to Groundwater (m) Oct 12-14/10	Groundwater Elevation (m) Oct 12-14/10
PZ-1	frozen	n/a	0.02	327.38			0.21	327.19	0.46	326.94
PZ-1	frozen	n/a	-0.03	327.43			0.26	327.14	0.42	326.98
PZ-2	frozen	n/a	0.05	326.15			0.04	326.16	0.30	325.90
PZ-2	frozen	n/a	0.15	326.05			0.38	325.82	0.33	325.87
PZ-4	frozen	n/a	0.13	322.17			0.23	322.07	0.16	322.14
PZ-4	frozen	n/a	0.02	322.28			0.24	322.06	0.13	322.17
PZ-7	frozen	n/a	-0.06	321.46			-0.02	321.42	-0.07	321.47
PZ-7	frozen	n/a	-0.07	321.47			-0.02	321.42	-0.07	321.47
PZ-8	frozen	n/a	-0.03	318.53	-0.05	318.55	-0.03	318.53	0.13	318.37
PZ-8	frozen	n/a	-0.03	318.53	-0.04	318.54	-0.02	318.52	0.12	318.38
PZ-9	frozen	n/a	-0.27	326.42			0.19	325.96	0.36	325.79
PZ-9	frozen	n/a	-0.18	326.33			0.26	325.89	0.53	325.62
PZ-10					installed	n/a	0.55	317.75	0.42	317.89
PZ-10					installed	n/a	0.78	317.52	0.56	317.75
PZ-11					0.13	320.13	0.37	319.88	0.14	320.11
PZ-11					0.53	319.73	1.10	319.15	0.28	319.97
PZ-12										
PZ-13										
PZ-14										

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Piezometer Groundwater Elevation Data

Piezometer Number	Depth to Groundwater (m) Jan 18, 19/11	Groundwater Elevation (m) Jan 18, 19/11	Depth to Groundwater (m) Apr 27, 28/11	Groundwater Elevation (m) Apr 27, 28/11	Depth to Groundwater (m) Jul 18, 19/11	Groundwater Elevation (m) Jul 18, 19/11	Depth to Groundwater (m) Oct 20, 25/11	Groundwater Elevation (m) Oct 20, 25/11
PZ-1	0.57	326.83	0.02	327.38	-0.01	327.41	0.14	327.26
PZ-1	0.62	326.78	-0.07	327.47	-0.10	327.50	0.16	327.24
PZ-2	0.40	325.80	0.00	326.20	-0.02	326.22	-0.01	326.21
PZ-2	0.44	325.76	0.09	326.11	0.11	326.09	0.11	326.09
PZ-4	0.11	322.19	0.13	322.17	0.14	322.16	0.00	322.30
PZ-4	-0.06	322.36	0.00	322.30	0.16	322.14	0.00	322.30
PZ-7	-0.04	321.44	-0.05	321.45	0.02	321.38	-0.10	321.50
PZ-7	-0.06	321.46	-0.07	321.47	0.02	321.38	-0.11	321.51
PZ-8	0.11	318.39	-0.10	318.60	0.09	318.41	n/a	n/a
PZ-8	0.11	318.39	n/a	n/a	0.08	318.42	-0.23	318.73
PZ-9	0.38	325.77	-0.43	326.57	-0.12	326.27	0.17	325.99
PZ-9	0.50	325.66	-0.43	326.58	-0.10	326.25	0.17	325.98
PZ-10	0.42	317.88	-0.16	318.46	0.06	318.24	n/a	n/a
PZ-10	0.55	317.75	-0.17	318.47	0.11	318.19	n/a	n/a
PZ-11	0.11	320.14	-0.02	320.27	0.14	320.11	n/a	n/a
PZ-11	0.26	320.00	-0.03	320.28	0.43	319.83	n/a	n/a
PZ-12					dry	dry	dry	dry
PZ-13								
PZ-14								

Hanlon Creek Business Park - Groundwater Monitoring Program 2003 - 2014

Piezometer Groundwater Elevation Data

Piezometer Number	Depth to Groundwater (m) Jan 12, 18/12	Groundwater Elevation (m) Jan 12, 18/12	Depth to Groundwater (m) Apr 13, 16/12	Groundwater Elevation (m) Apr 13, 16/12	Depth to Groundwater (m) Jul 16, 19/12	Groundwater Elevation (m) Jul 16, 19/12	Depth to Groundwater (m) Oct 16, 18/12	Groundwater Elevation (m) Oct 16, 18/12
PZ-1	0.25	327.15	0.22	327.18	0.75	326.65	dry	dry
PZ-1	0.24	327.16	0.21	327.19	0.66	326.74	0.86	326.54
PZ-2	0.22	325.98	0.36	325.84	0.73	325.47	0.47	325.73
PZ-2	0.31	325.89	0.39	325.81	0.70	325.50	0.53	325.67
PZ-4	0.12	322.18	0.17	322.13	0.35	321.95	0.20	322.10
PZ-4	0.00	322.30	0.08	322.22	0.37	321.93	0.13	322.17
PZ-7	-0.03	321.43	0.00	321.40	0.04	321.36	-0.04	321.44
PZ-7	-0.09	321.49	-0.01	321.41	0.04	321.36	-0.05	321.45
PZ-8	0.07	318.43	0.04	318.46	0.35	318.15	0.11	318.39
PZ-8	-0.05	318.55	0.04	318.47	0.35	318.16	0.11	318.40
PZ-9	-0.23	326.38	-0.03	326.18	0.45	325.71	dry	dry
PZ-9	-0.22	326.37	-0.02	326.17	0.57	325.59	0.83	325.32
PZ-10	-0.09	318.39	0.10	318.20	0.56	317.74	0.24	318.07
PZ-10	-0.09	318.39	0.13	318.18	0.94	317.36	0.40	317.90
PZ-11	0.02	320.24	0.15	320.10	0.22	320.03	0.09	320.16
PZ-11	0.28	319.97	0.41	319.85	0.56	319.69	0.34	319.92
PZ-12	0.60	325.91	dry	dry	dry	dry	0.90	325.60
PZ-13								
PZ-14								

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Piezometer Groundwater Elevation Data

Piezometer Number	Depth to Groundwater (m) Jan 10, 11/13	Groundwater Elevation (m) Jan 10, 11/13	Depth to Groundwater (m) Apr 25, 26/13	Groundwater Elevation (m) Apr 25, 26/13	Depth to Groundwater (m) Jul 15, 16/13	Groundwater Elevation (m) Jul 15, 16/13	Depth to Groundwater (m) Oct 23, 24/13	Groundwater Elevation (m) Oct 23, 24/13
PZ-1	0.65	326.75	0.03	327.37	0.07	327.33	0.22	327.18
PZ-1	0.69	326.71	-0.06	327.46	0.03	327.37	0.21	327.19
PZ-2	0.39	325.81	0.10	326.10	0.26	325.94	0.20	326.00
PZ-2	0.43	325.77	0.15	326.05	0.32	325.88	0.25	325.95
PZ-4	0.17	322.13	0.12	322.18	0.19	322.11	0.16	322.14
PZ-4	0.05	322.25	-0.01	322.31	0.11	322.19	0.00	322.30
PZ-7	-0.02	321.42	0.00	321.40	0.01	321.39	-0.05	321.45
PZ-7	-0.03	321.43	-0.03	321.43	0.00	321.40	-0.07	321.47
PZ-8	0.03	318.47	-0.13	318.63	0.06	318.44	-0.04	318.54
PZ-8	0.03	318.48	-0.13	318.63	0.05	318.45	-0.05	318.55
PZ-9	0.41	325.74	0.39	325.76	0.33	325.82	0.37	325.78
PZ-9	0.41	325.75	-0.42	326.57	-0.03	326.18	0.11	326.04
PZ-10	0.09	318.21	-0.18	318.48	0.04	318.26	-0.11	318.41
PZ-10	0.11	318.19	-0.18	318.48	0.05	318.25	-0.11	318.41
PZ-11	0.11	320.14	0.04	320.22	0.12	320.13	0.01	320.24
PZ-11	0.37	319.88	0.25	320.00	0.44	319.81	0.30	319.95
PZ-12	0.66	325.84	0.51	326.00	0.52	325.98	0.50	326.01
PZ-13					0.05	324.15	-0.01	324.21
PZ-14					0.45	323.75	0.01	324.19

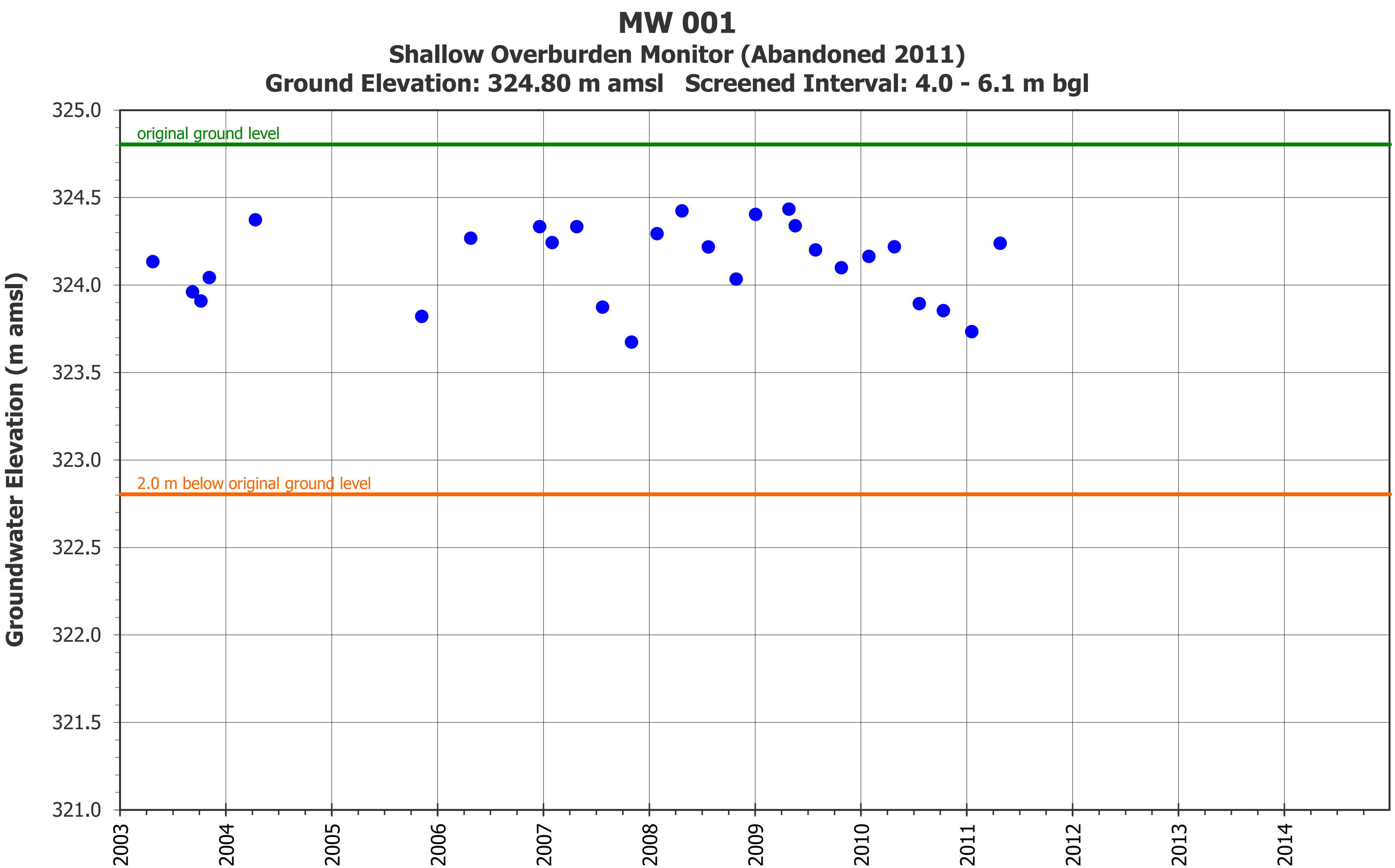
Hanlon Creek Business Park - Groundwater Monitoring Program 2003 - 2014

Piezometer Groundwater Elevation Data

Piezometer Number	Depth to Groundwater (m) Jan 13, 14/14	Groundwater Elevation (m) Jan 13, 14/14	Depth to Groundwater (m) Apr 22, 23/14	Groundwater Elevation (m) Apr 22, 23/14	Depth to Groundwater (m) Jul 14, 15/14	Groundwater Elevation (m) Jul 14, 15/14	Depth to Groundwater (m) Oct 9, 10/14	Groundwater Elevation (m) Oct 9, 10/14
PZ-1	frozen	frozen	-0.03	327.43	0.04	327.36	0.16	327.24
PZ-1	frozen	frozen	-0.08	327.48	0.03	327.37	0.17	327.23
PZ-2	frozen	frozen	0.04	326.16	0.23	325.97	0.23	325.97
PZ-2	frozen	frozen	0.13	326.07	0.29	325.91	0.28	325.92
PZ-4	frozen	frozen	0.18	322.12	0.27	322.03	0.21	322.09
PZ-4	frozen	frozen	0.07	322.23	0.17	322.13	0.05	322.25
PZ-7	frozen	frozen	0.00	321.40	0.03	321.37	-0.05	321.45
PZ-7	frozen	frozen	-0.02	321.42	0.01	321.39	-0.06	321.46
PZ-8	-0.15	318.65	-0.10	318.60	0.09	318.41	0.00	318.50
PZ-8	-0.16	318.66	-0.15	318.65	0.09	318.41	-0.01	318.51
PZ-9	frozen	frozen	0.39	325.76	0.36	325.79	0.32	325.83
PZ-9	frozen	frozen	-0.42	326.57	-0.01	326.16	0.10	326.05
PZ-10	frozen	frozen	-0.14	318.44	0.34	317.96	-0.03	318.33
PZ-10	frozen	frozen	-0.14	318.44	0.36	317.94	-0.03	318.33
PZ-11	0.01	320.24	0.05	320.20	0.15	320.10	0.11	320.14
PZ-11	0.22	320.03	0.28	319.97	0.46	319.79	0.39	319.86
PZ-12	frozen	frozen	0.41	326.09	0.57	325.93	0.50	326.01
PZ-13	frozen	frozen	0.06	324.15	-	-	0.08	324.12
PZ-14	frozen	frozen	0.02	324.19	-	-	0.04	324.16

Appendix C

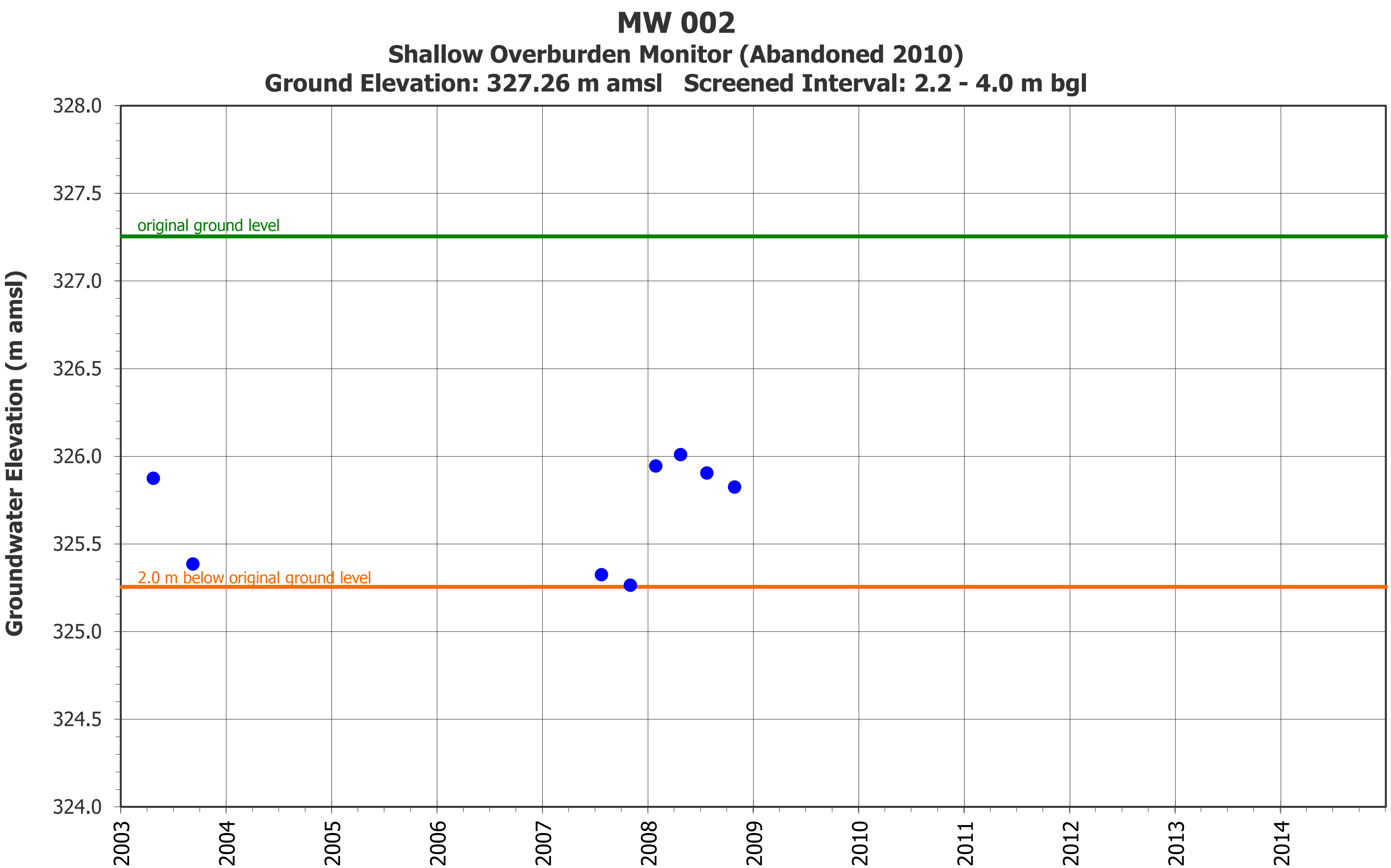
Groundwater Monitoring Graphs 2003 – 2014



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

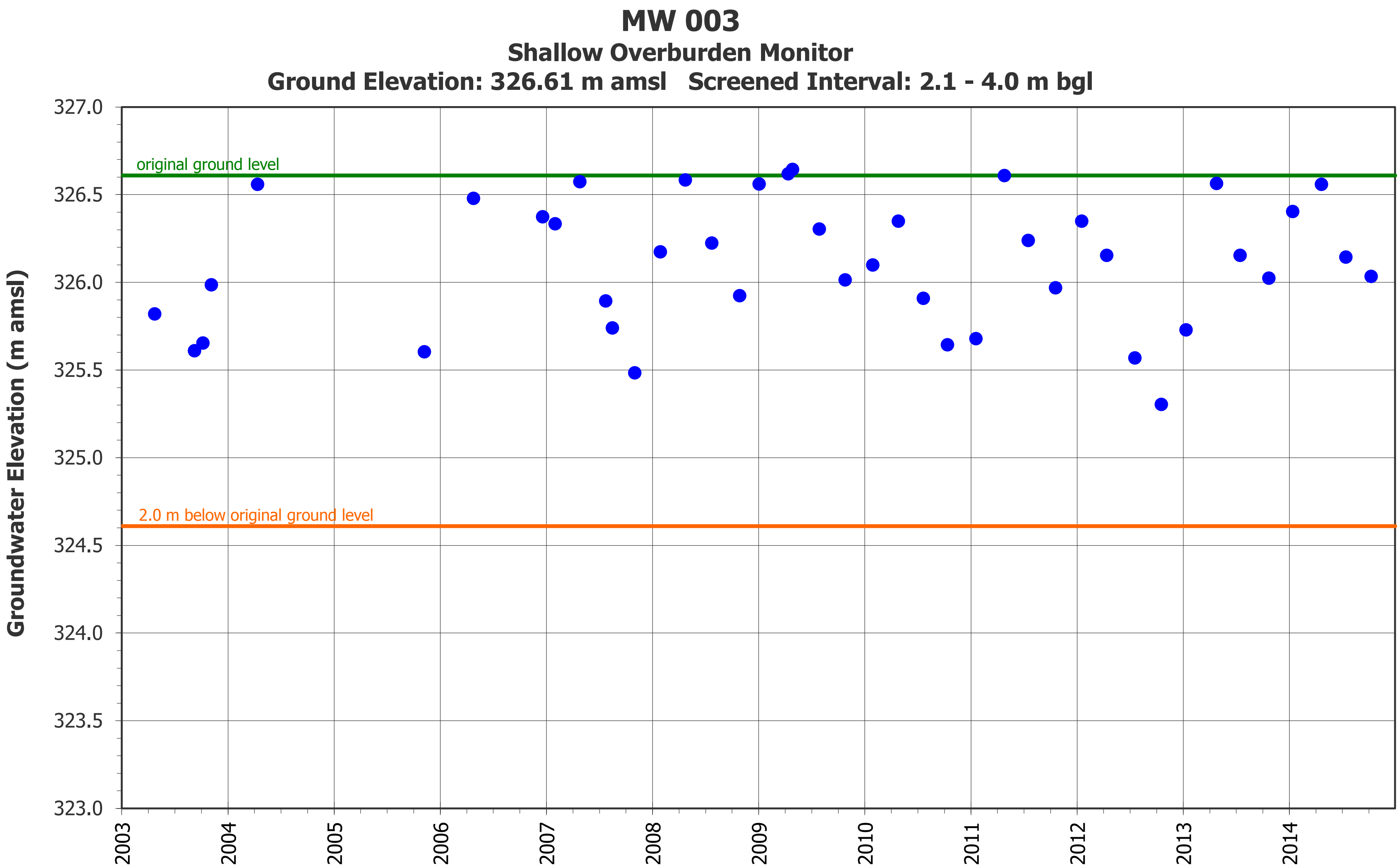
December 2014 **Phase 1 - Core PSW** **Graph C 1**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

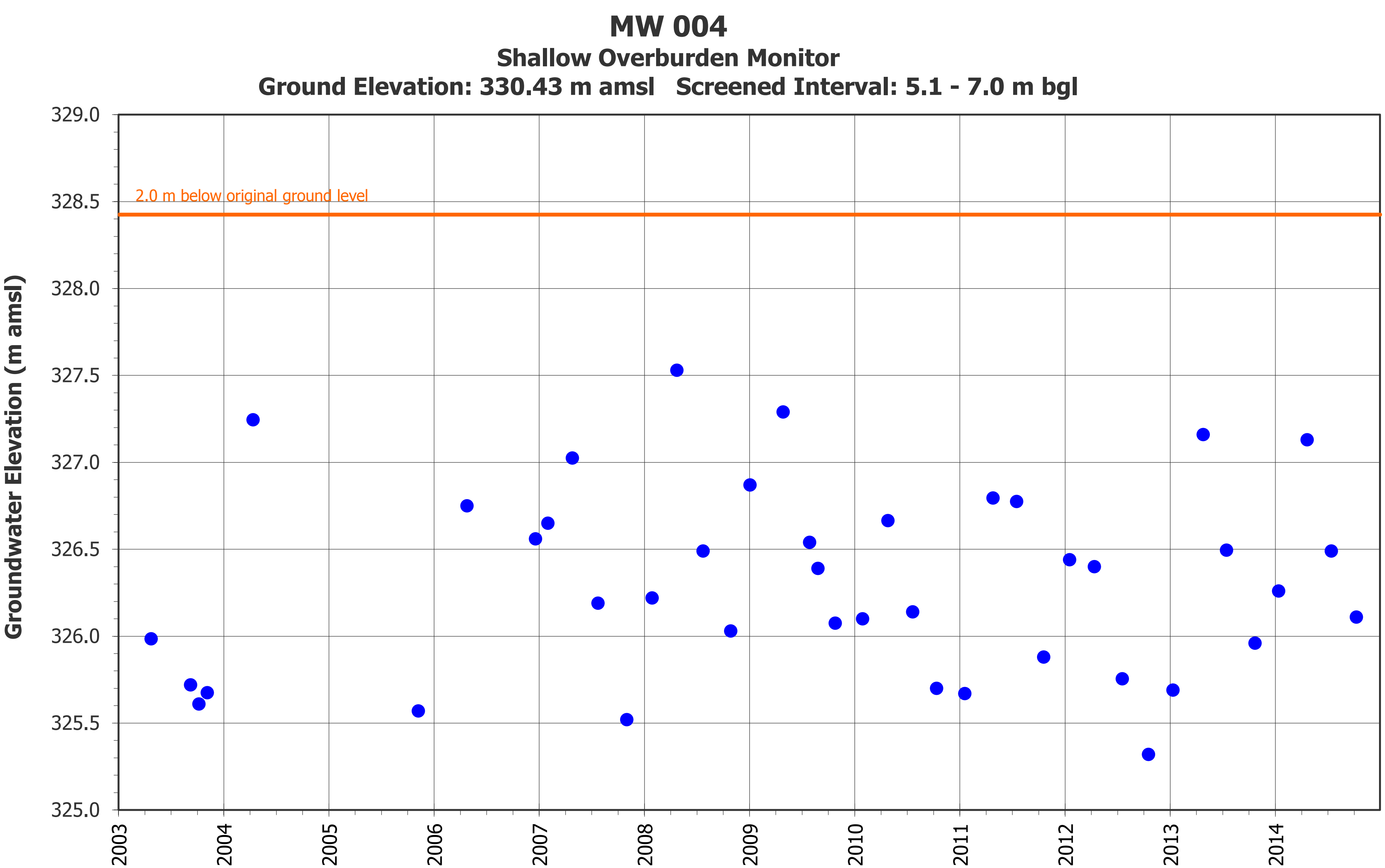
December 2014 **Phase 2 - Core PSW** **Graph C 2**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

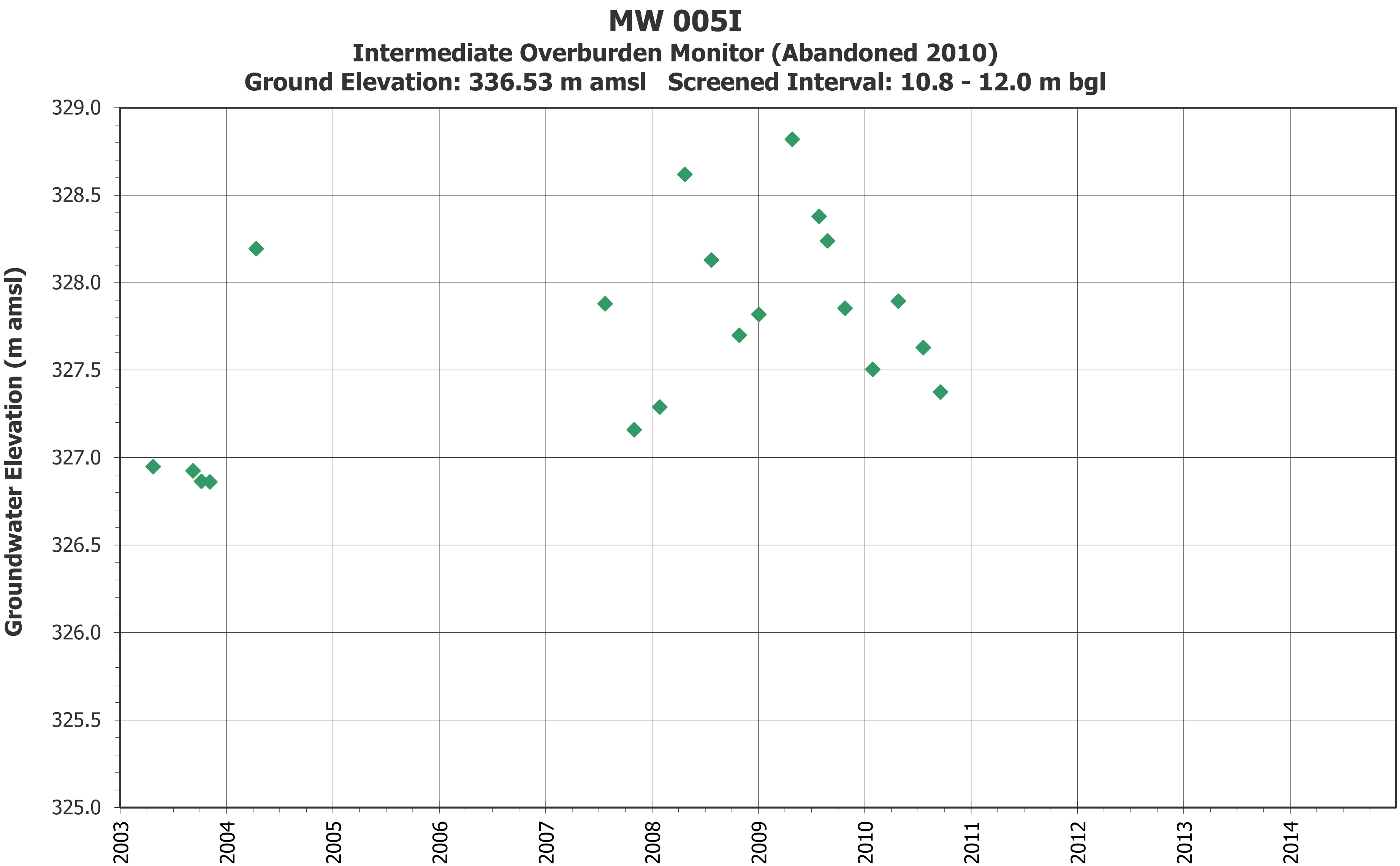
December 2014 **Phase 3 - Downey Rd. PSW** **Graph C 3**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

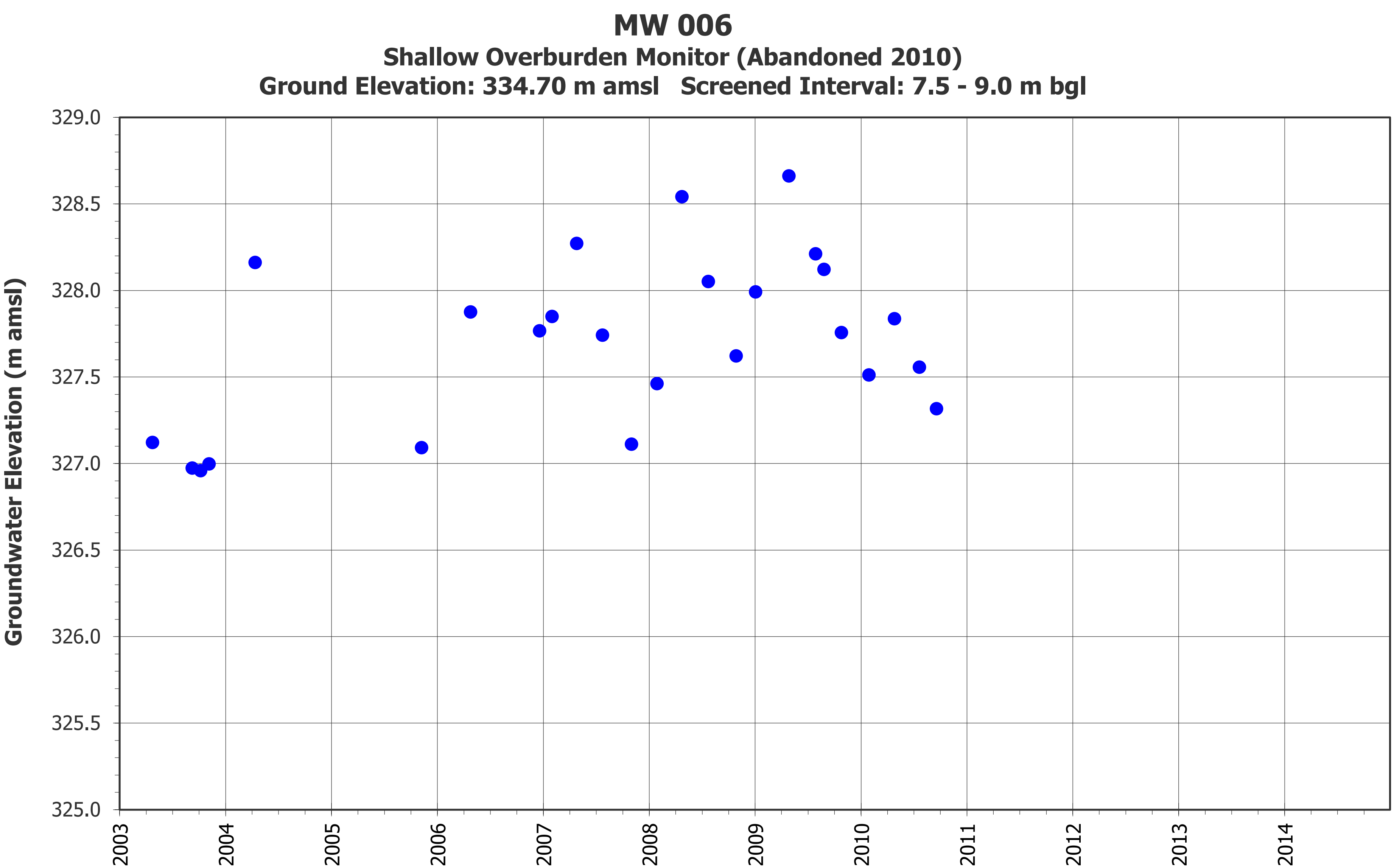
December 2014 **Phase 3 - Perimeter** **Graph C 4**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Perimeter** **Graph C 5**



Banks Groundwater Engineering Limited

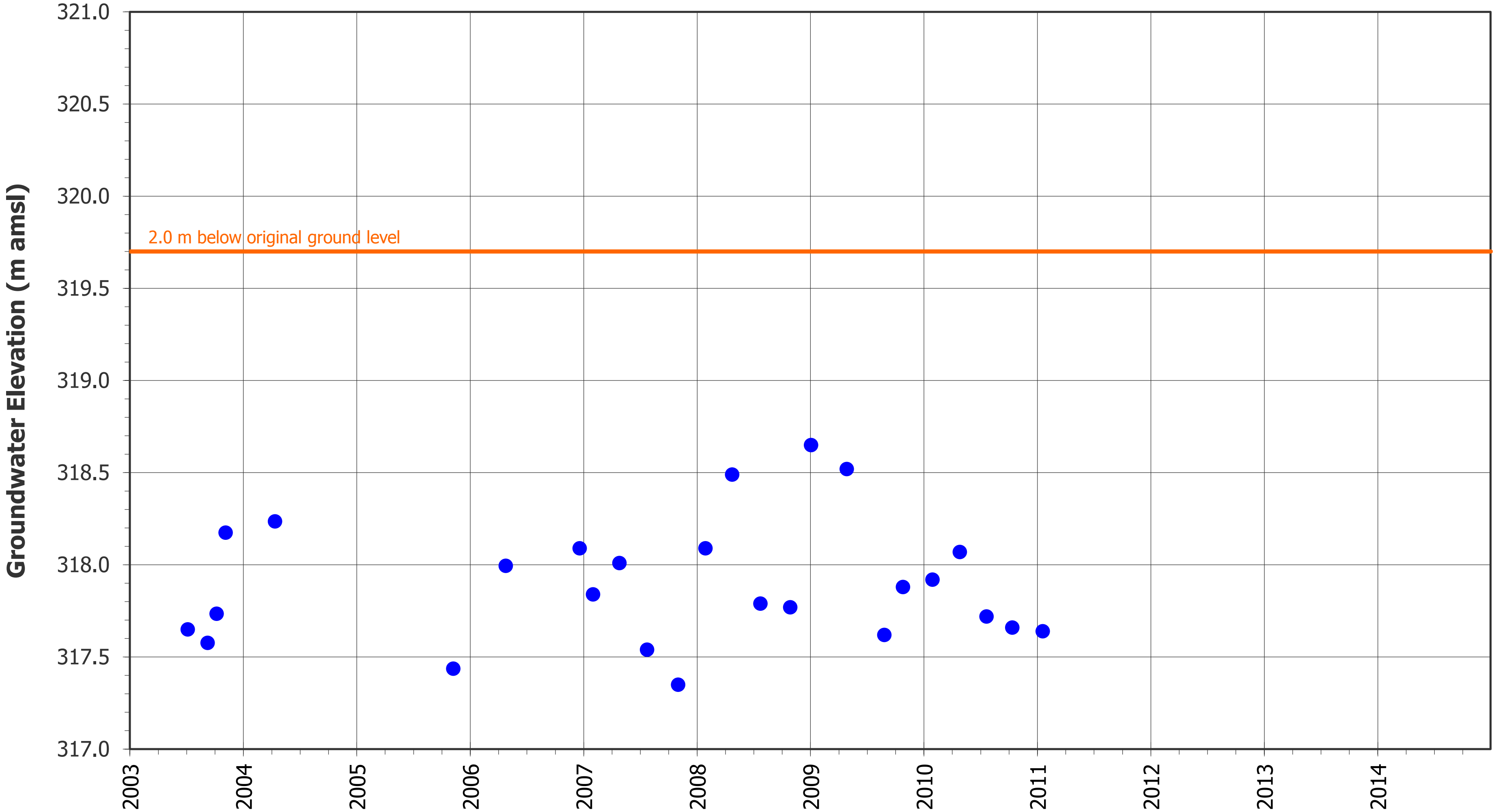
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Perimeter** **Graph C 6**

MW 101

Shallow Overburden Monitor (Abandoned 2011)

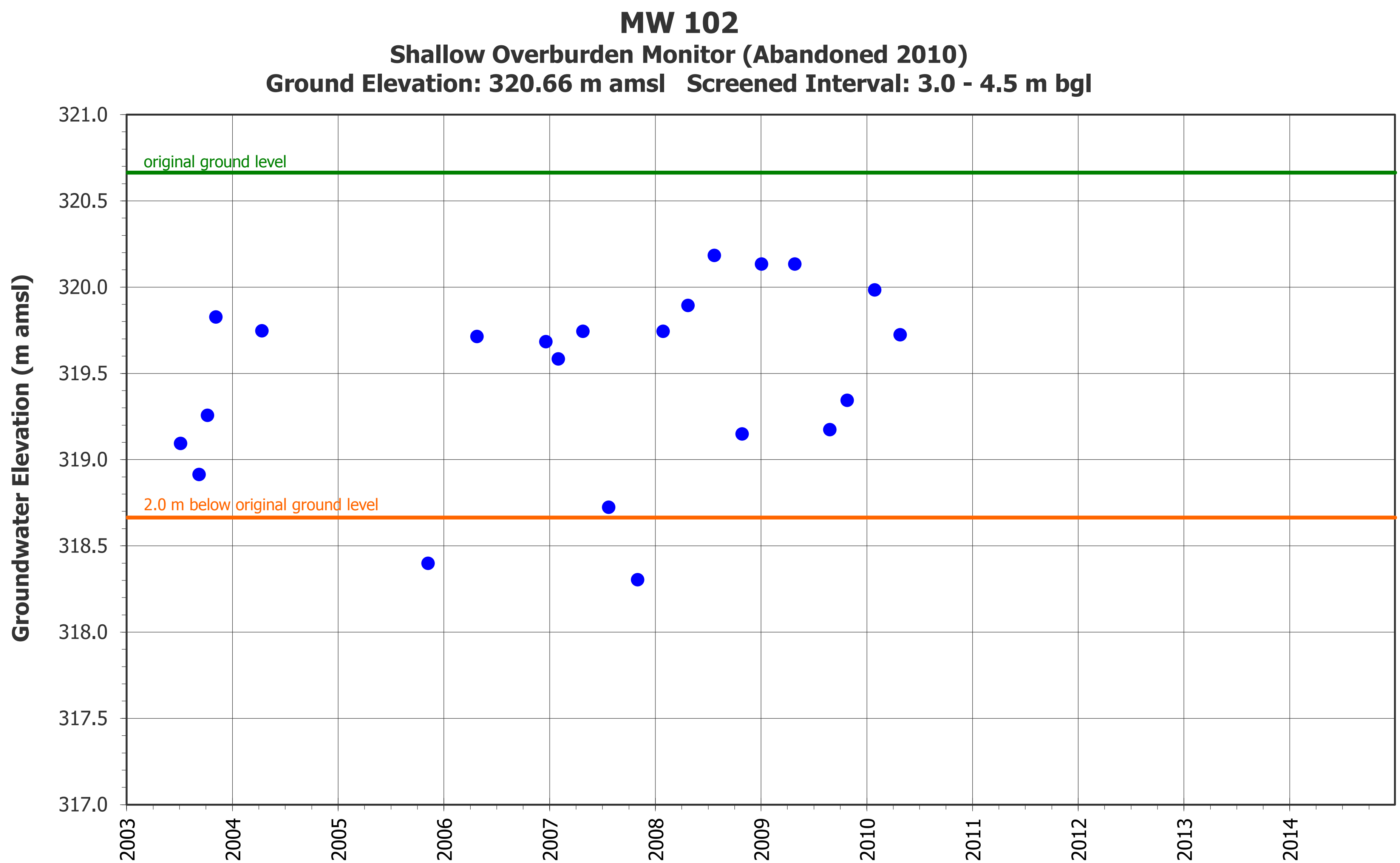
Ground Elevation: 321.70 m amsl   Screened Interval: 4.0 - 6.0 m bgl



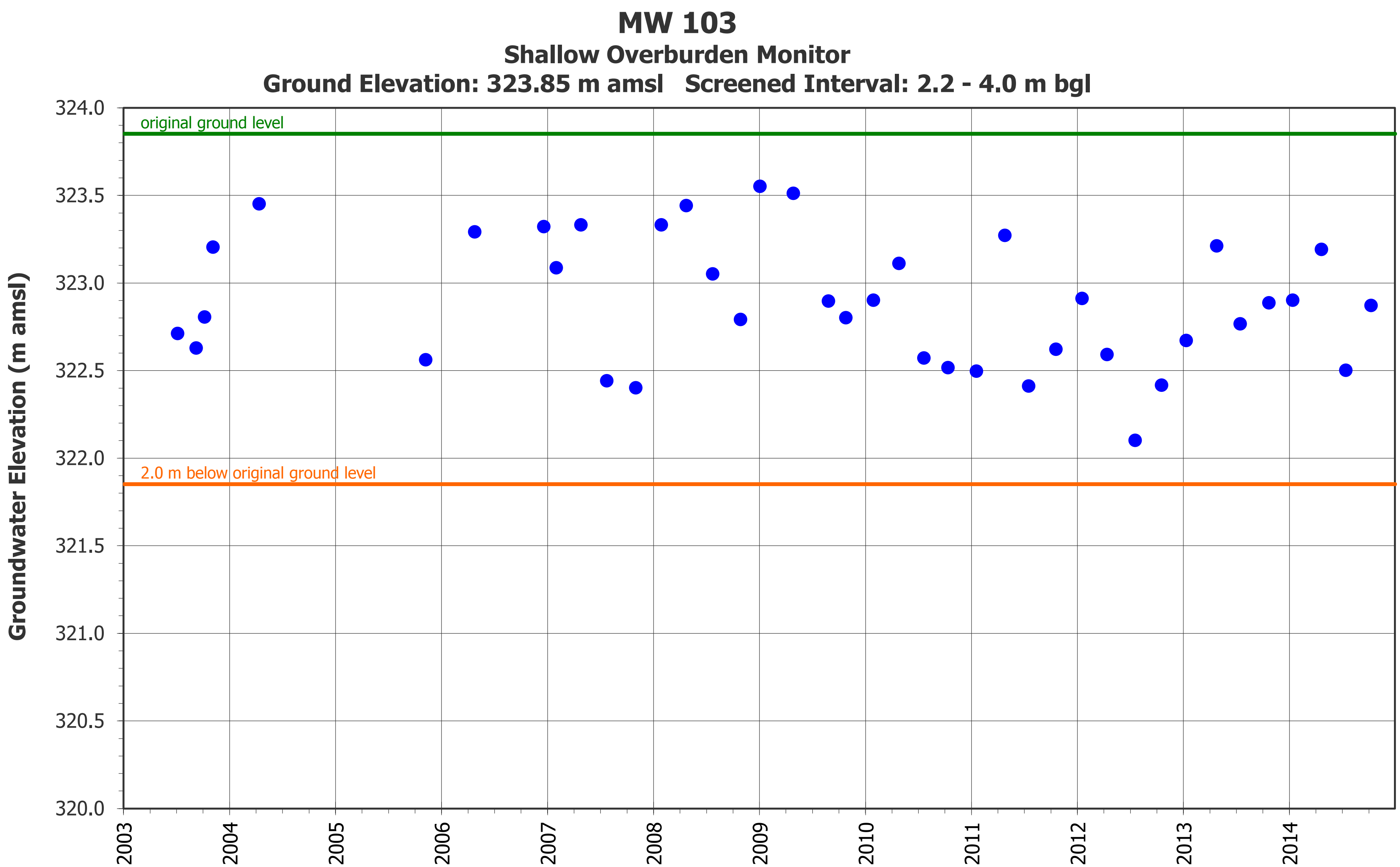
Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014   **Phase 1 - Core PSW**   **Graph C 7**



MW 102
Shallow Overburden Monitor (Abandoned 2010)
Ground Elevation: 320.66 m amsl   Screened Interval: 3.0 - 4.5 m bgl
Groundwater Elevation (m amsl)
original ground level
2.0 m below original ground level
321.0
320.5
320.0
319.5
319.0
318.5
318.0
317.5
317.0
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014



Banks Groundwater Engineering Limited

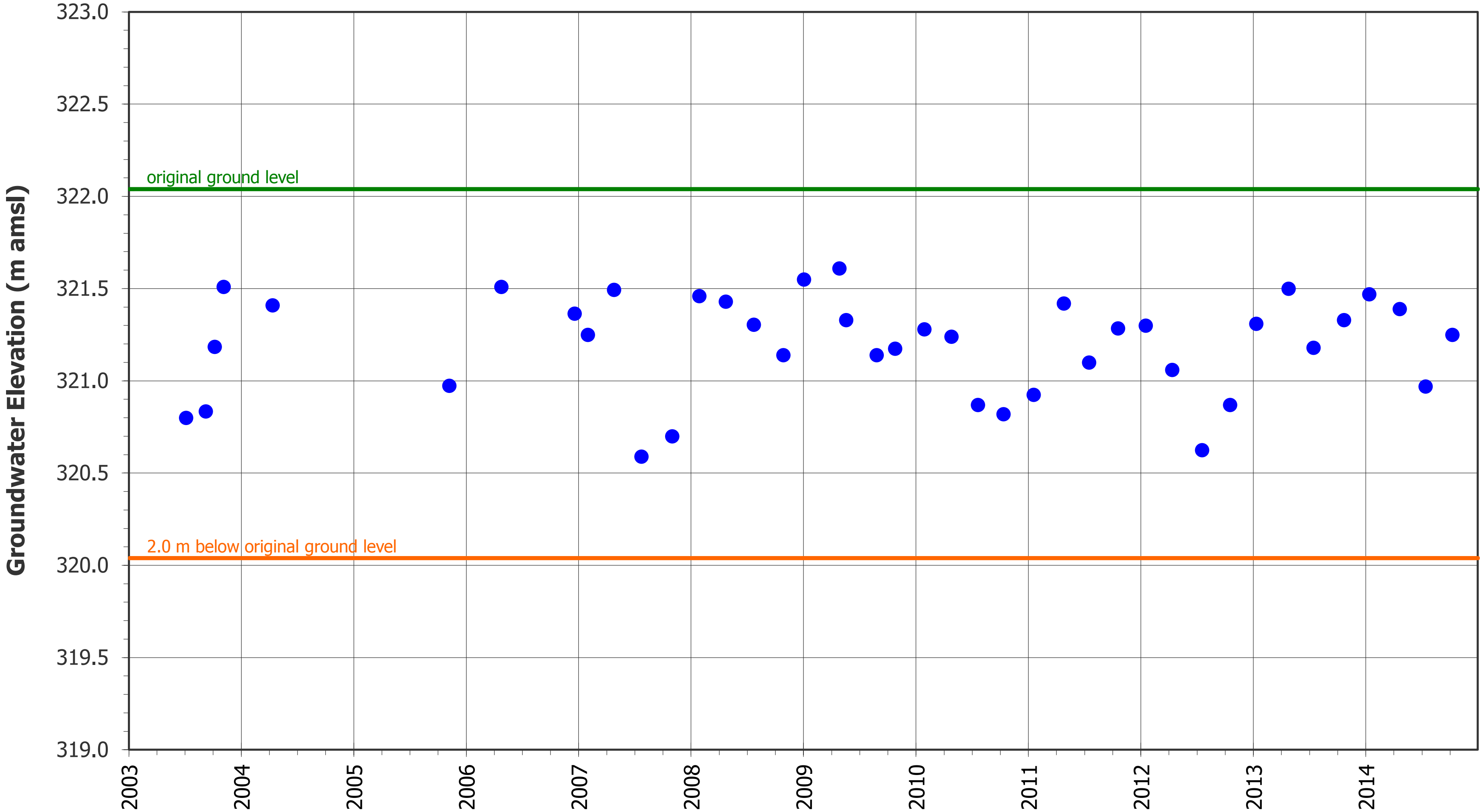
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph C 9**

MW 104

Shallow Overburden Monitor

Ground Elevation: 322.04 m amsl   Screened Interval: 2.3 - 4.1 m bgl



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

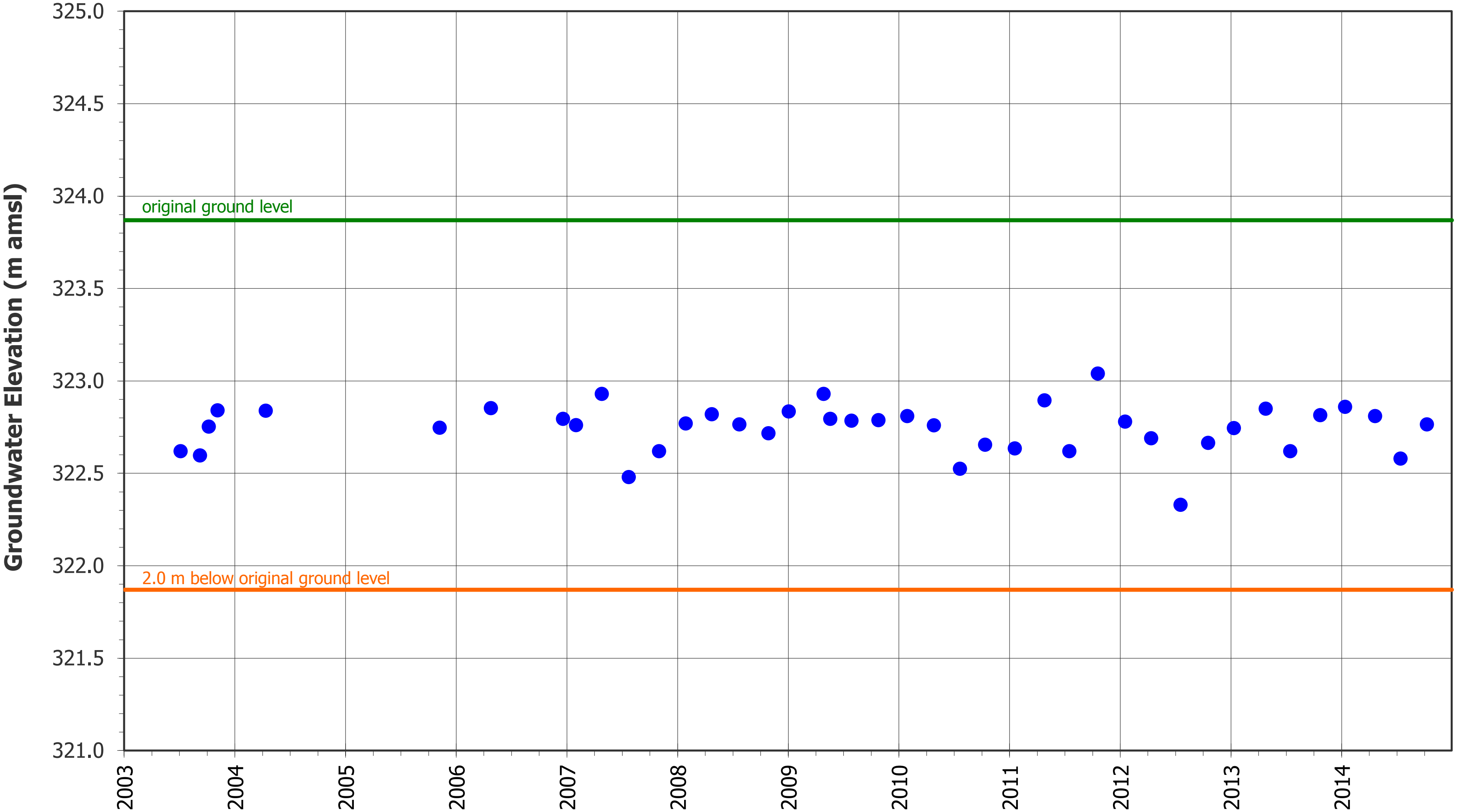
December 2014

Phase 1 - Core PSW   Graph C 10

MW 105

Shallow Overburden Monitor

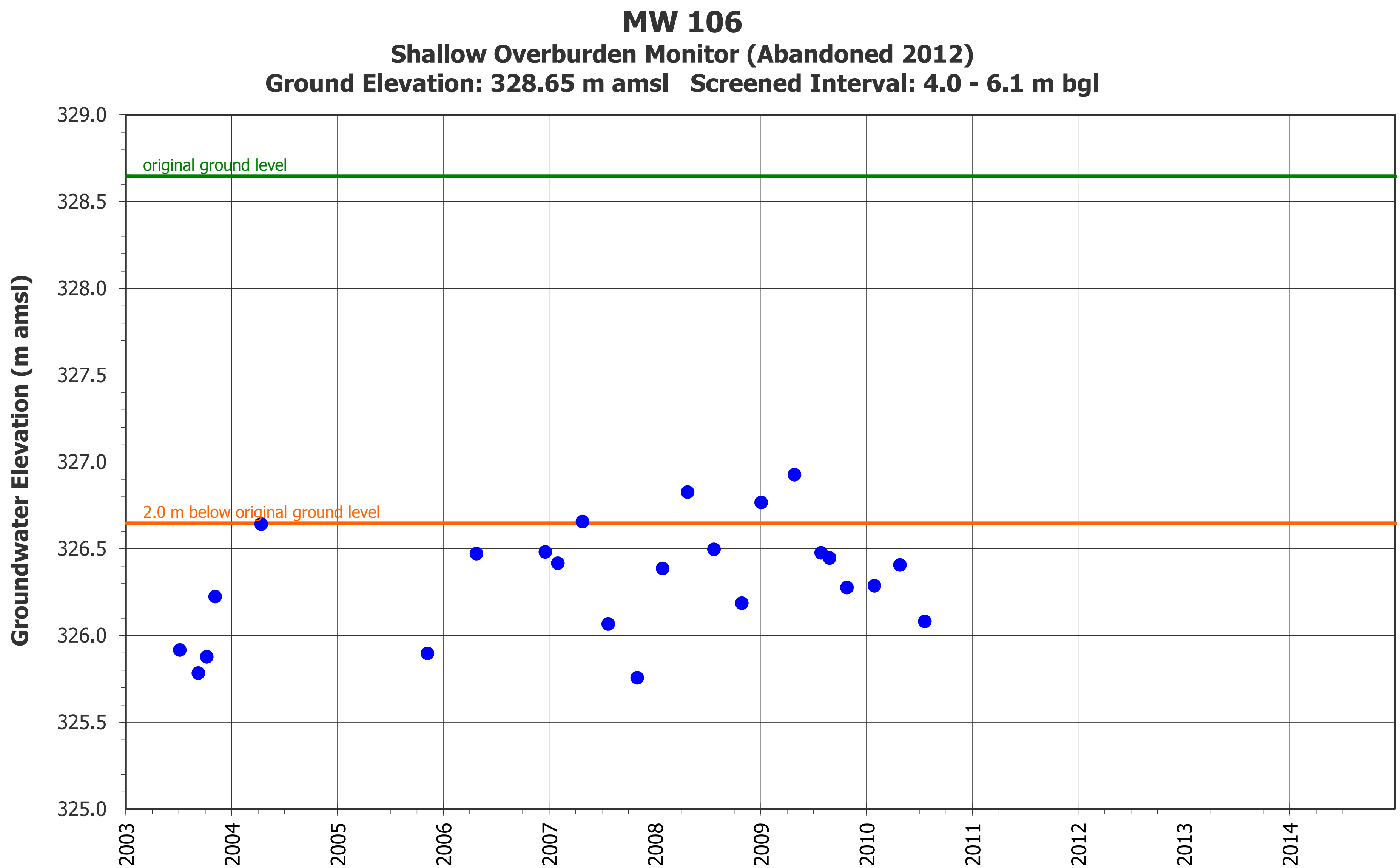
Ground Elevation: 323.87 m amsl   Screened Interval: 2.7 - 4.0 m bgl



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

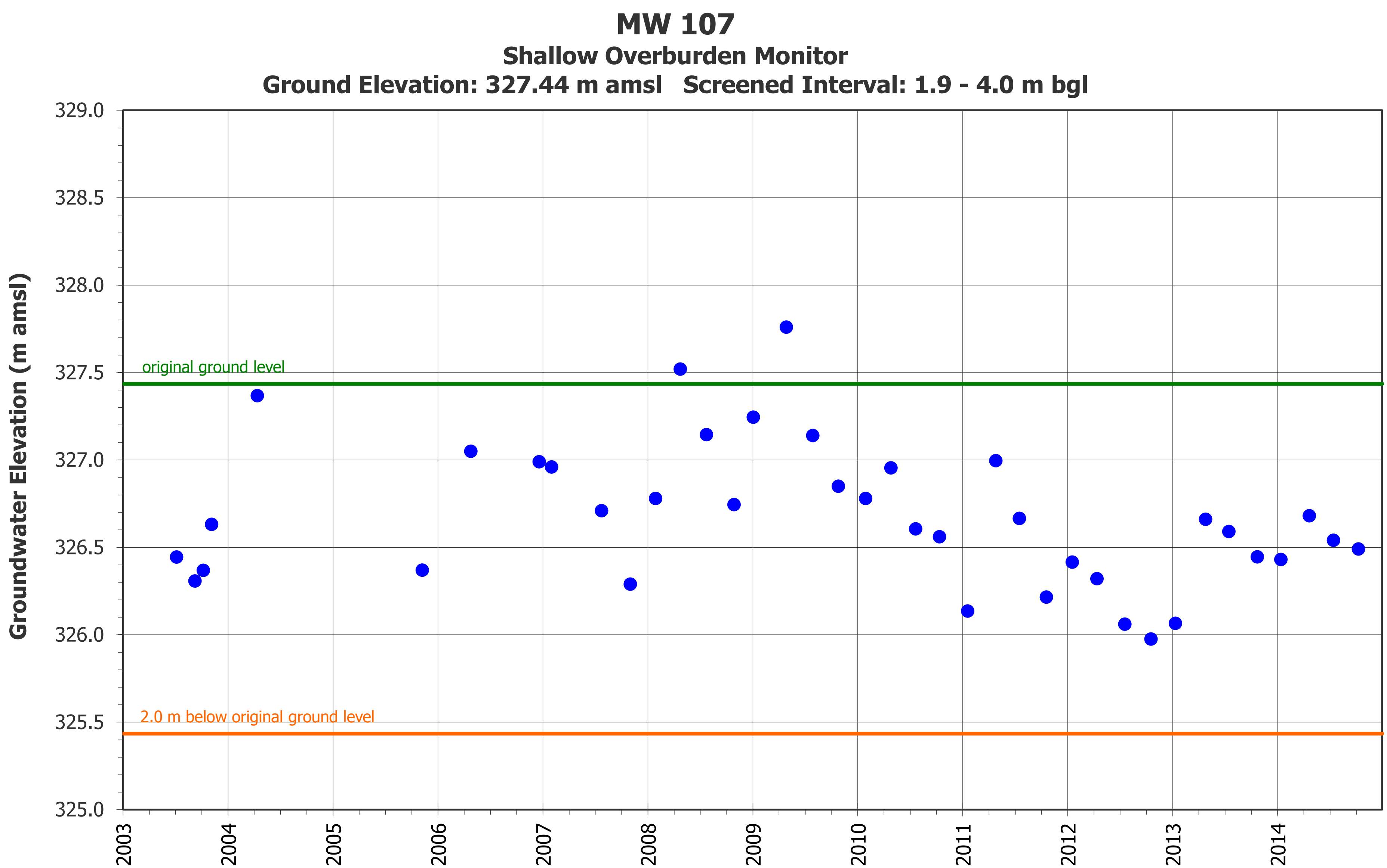
December 2014 **Phase 1 - Core PSW** **Graph C 11**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

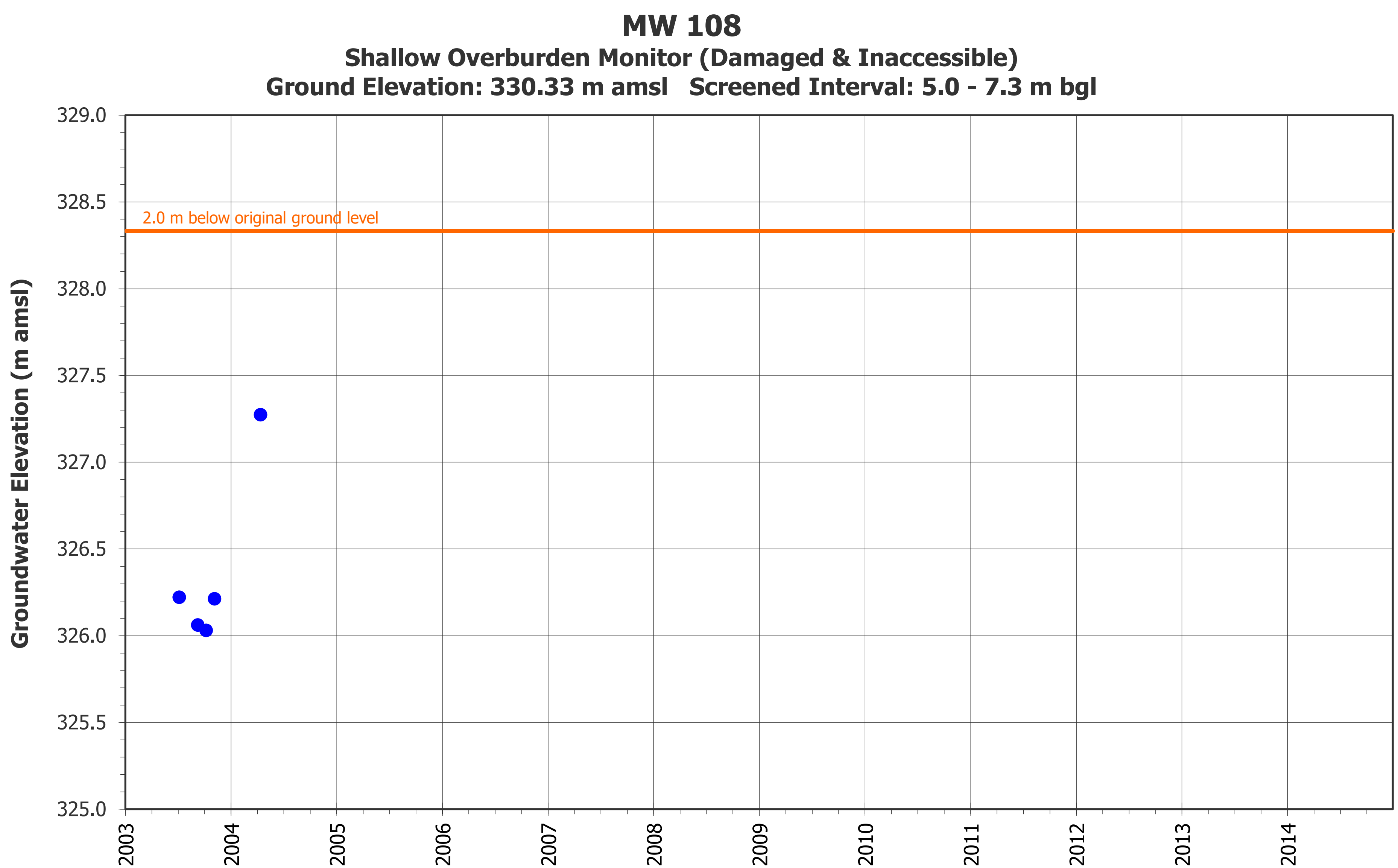
December 2014 **Phase 2 - Perimeter** **Graph C 12**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Perimeter** **Graph C 13**



Banks Groundwater Engineering Limited

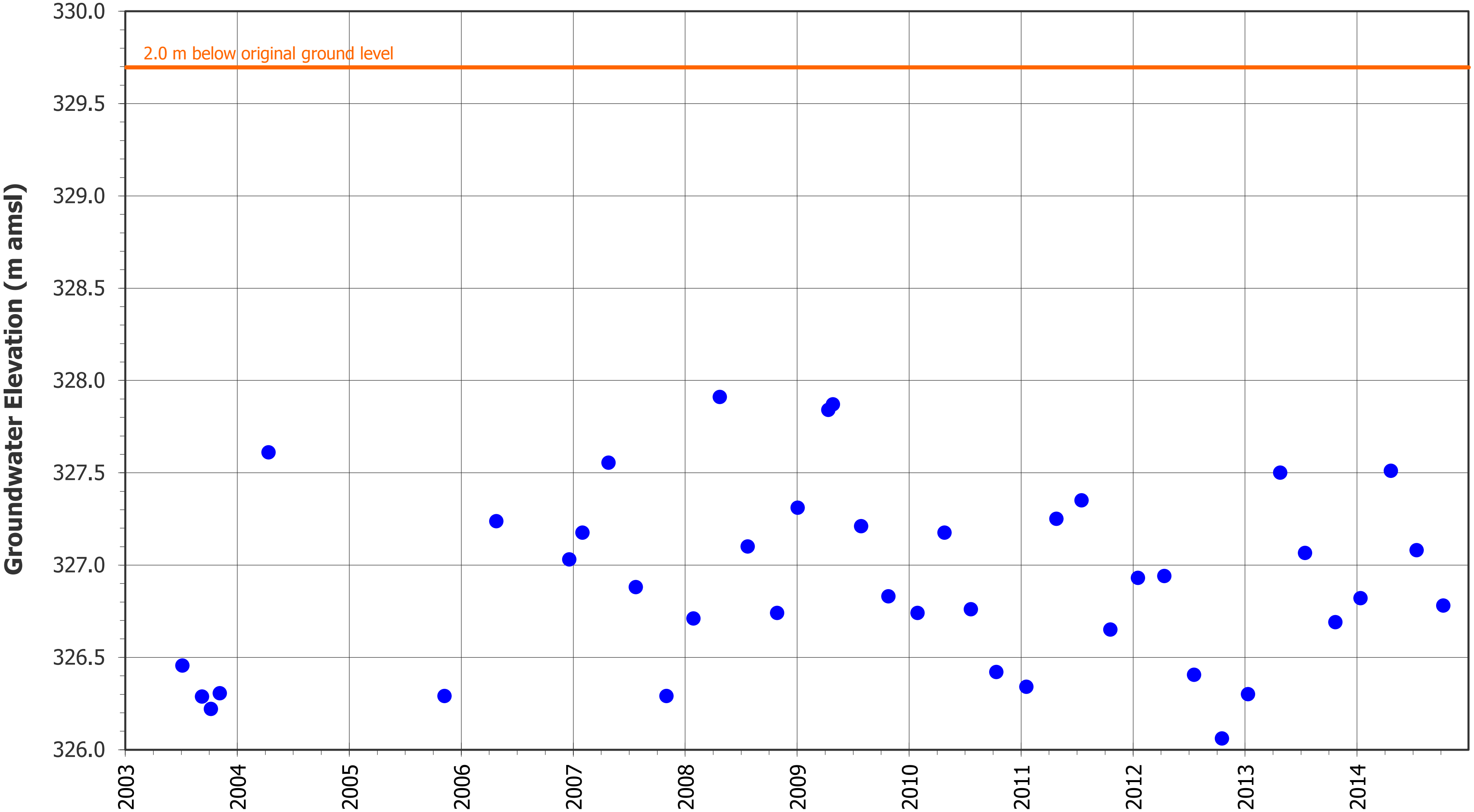
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 3 - Perimeter** **Graph C 14**

MW 109

Shallow Overburden Monitor

Ground Elevation: 331.70 m amsl   Screened Interval: 7.2 - 9.2 m bgl



Banks Groundwater Engineering Limited

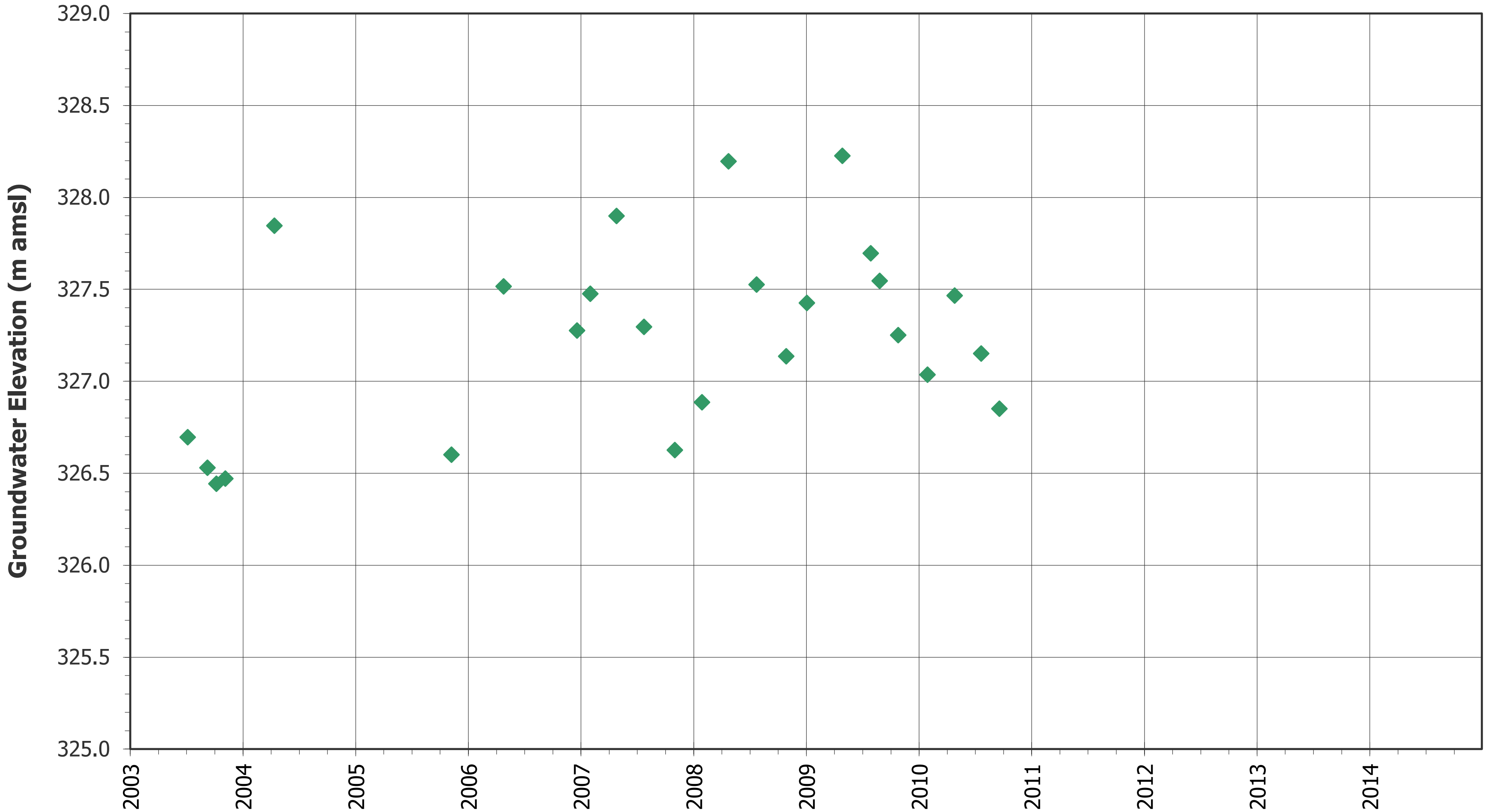
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 3 - Perimeter** **Graph C 15**

MW 110

Intermediate Overburden Monitor (Abandoned 2010)

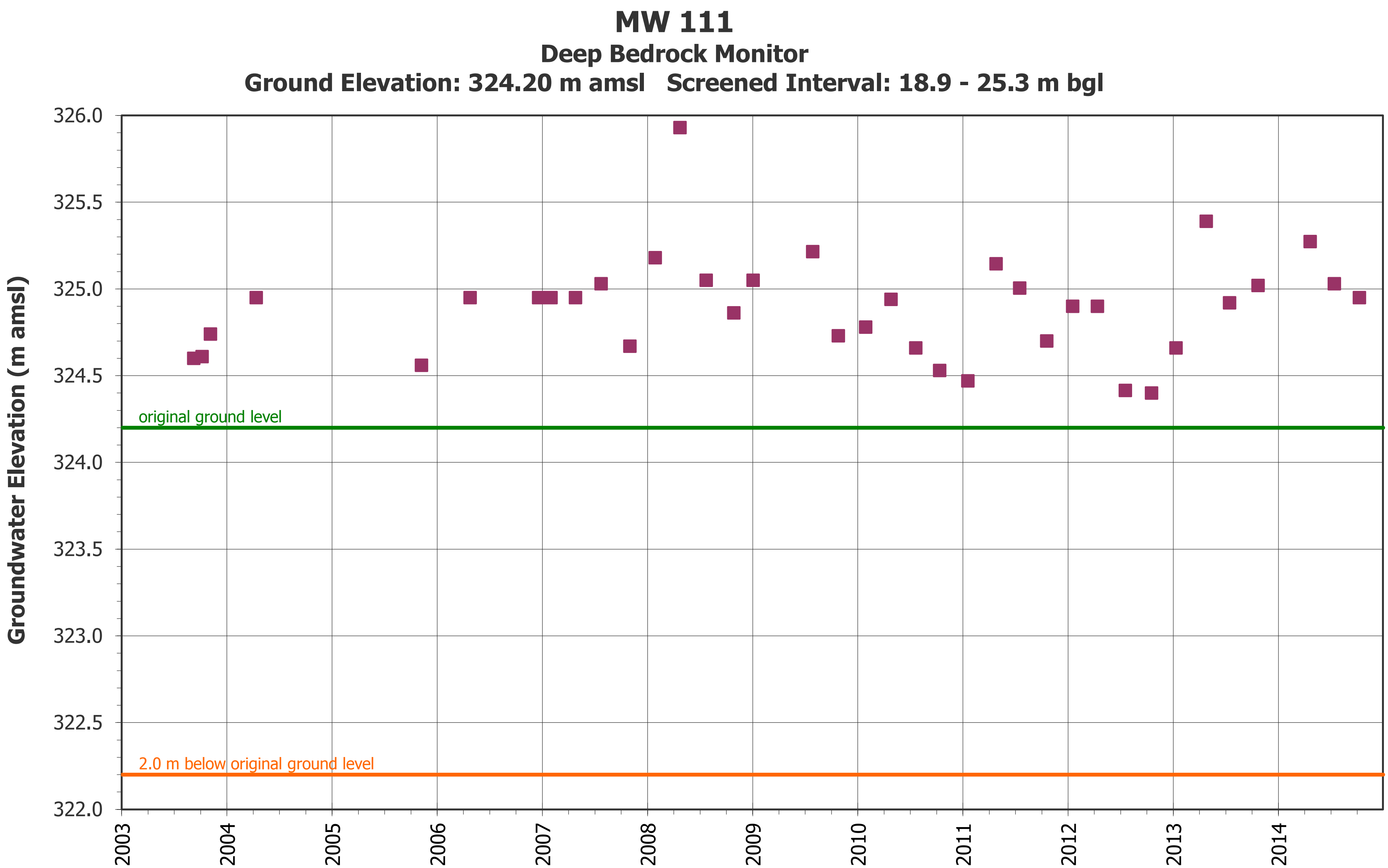
Ground Elevation: 339.59 m amsl   Screened Interval: 14.8 - 16.8 m bgl



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

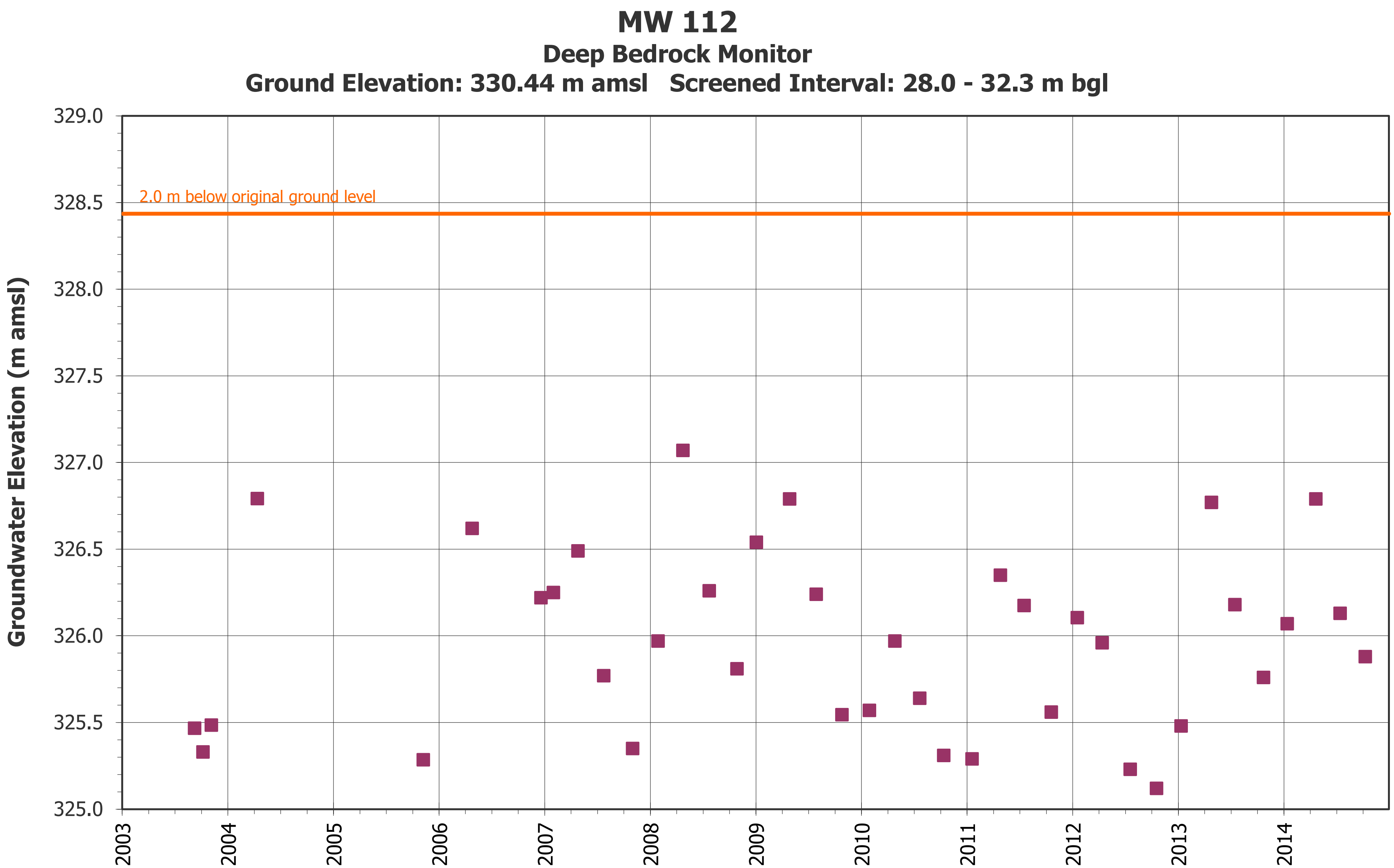
December 2014   **Phase 2 - Perimeter**   **Graph C 16**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

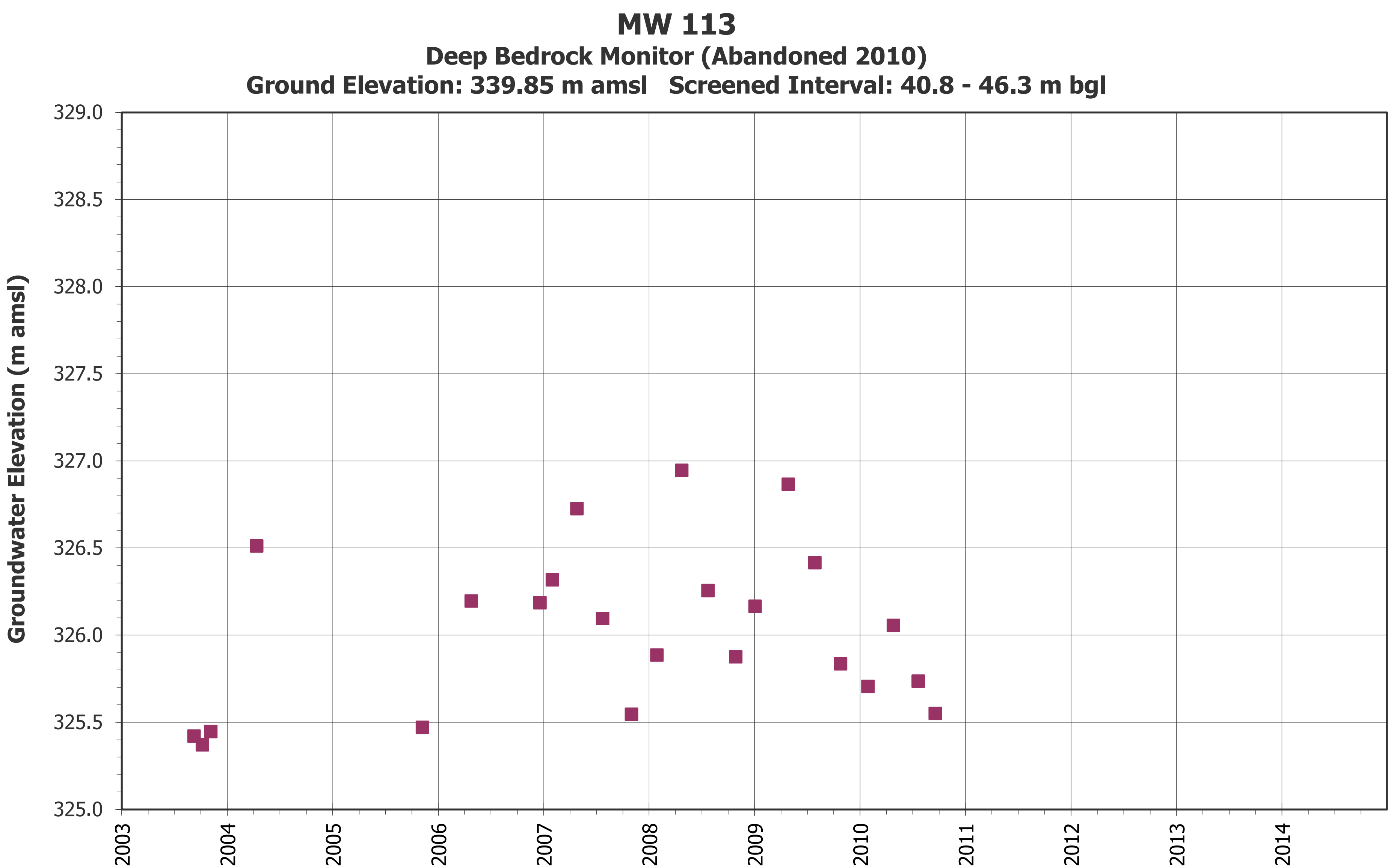
December 2014 **Phase 1 - Core PSW** **Graph C 17**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

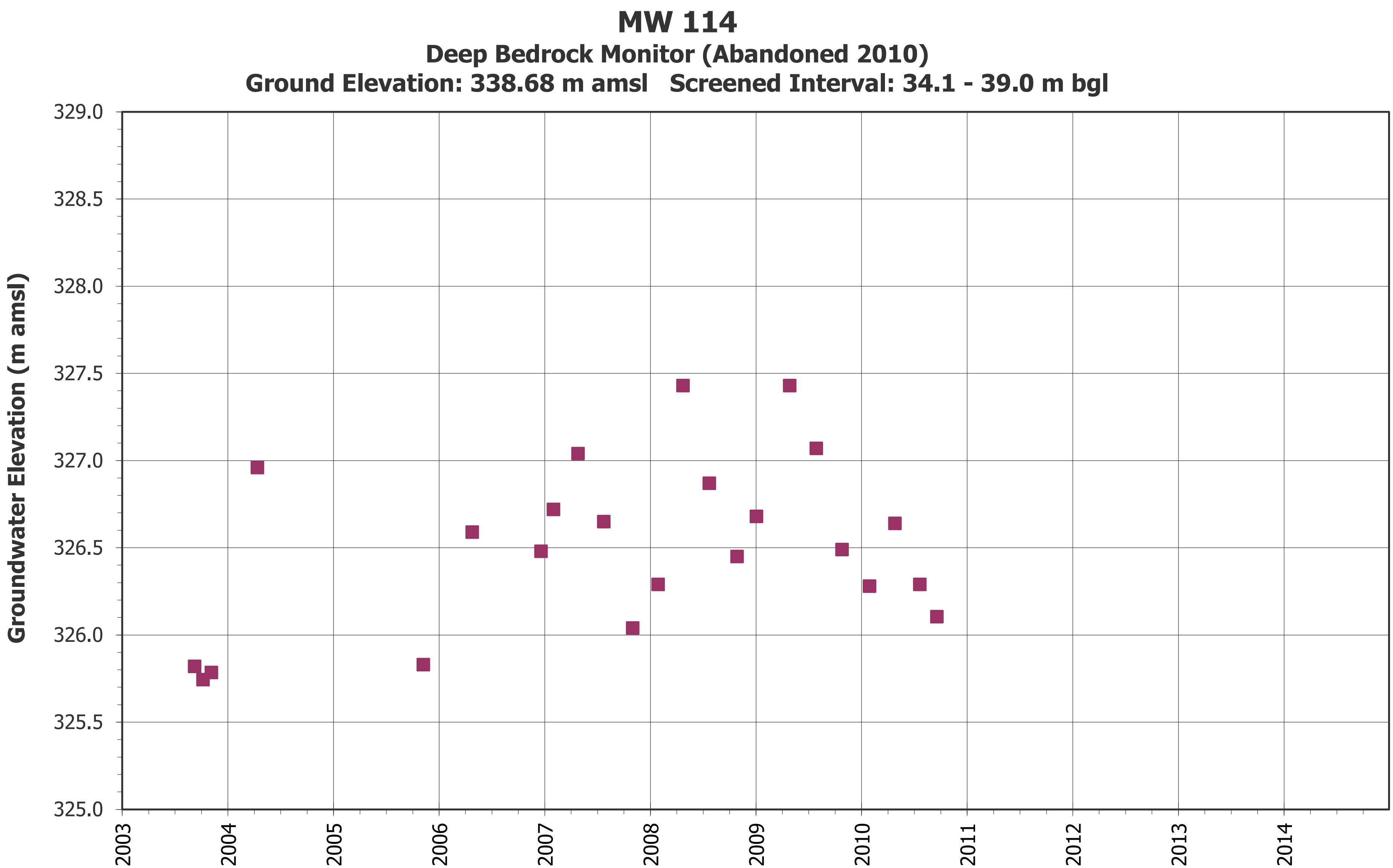
December 2014 **Phase 3 - Perimeter** **Graph C 18**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

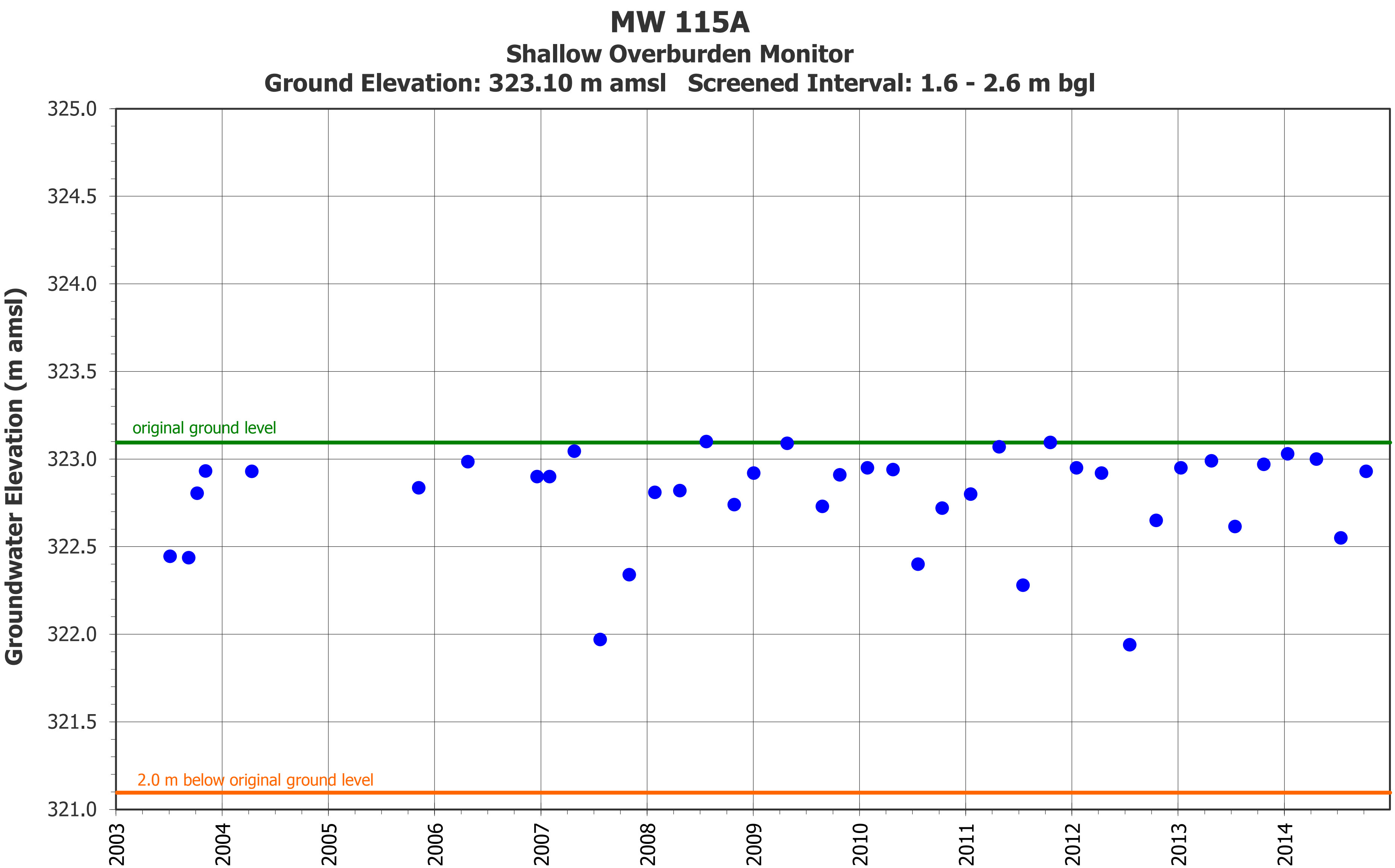
December 2014 **Phase 2 - Perimeter** **Graph C 19**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

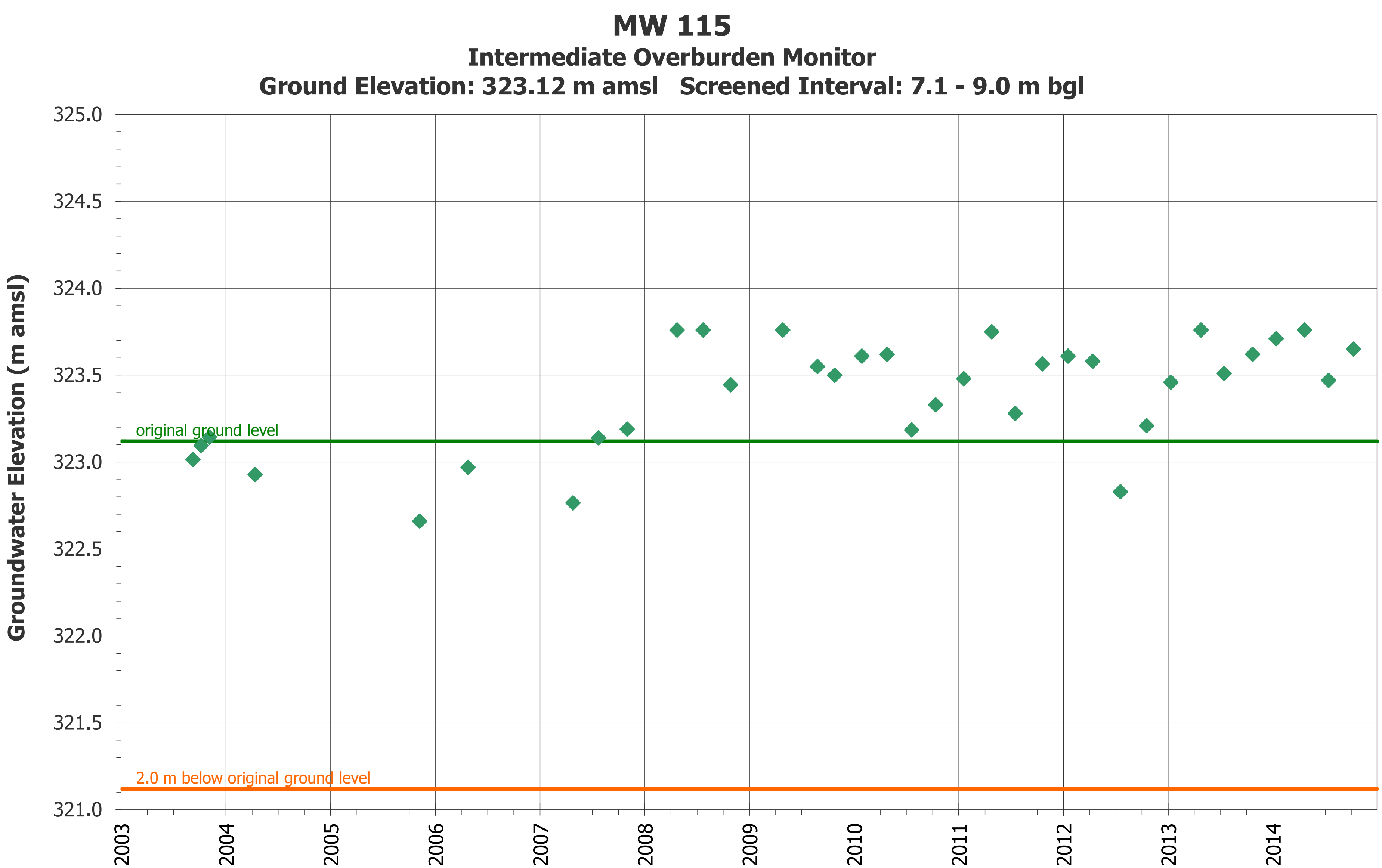
December 2014 **Phase 2 - Perimeter** **Graph C 20**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

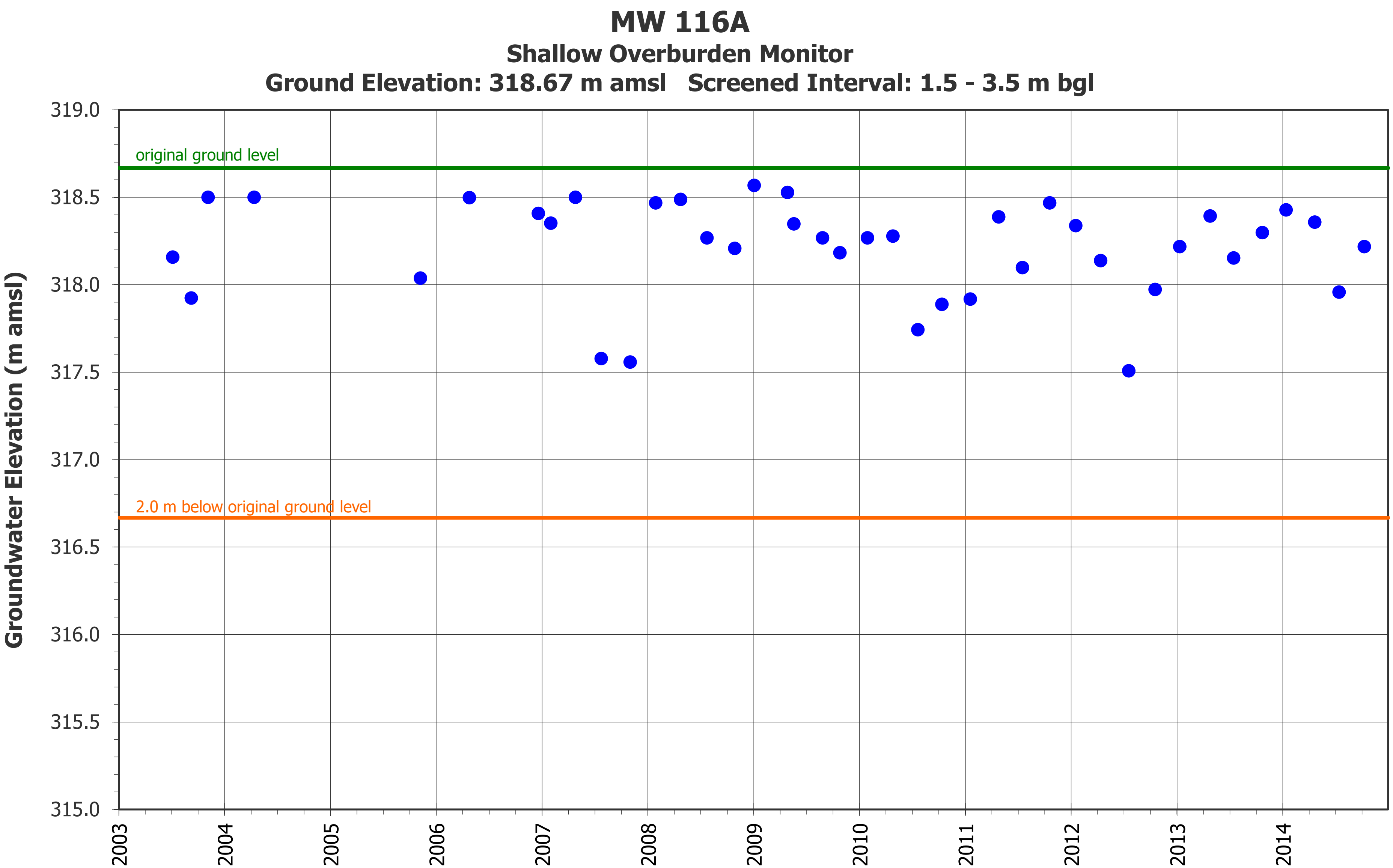
December 2014 **Phase 1 - Core PSW** **Graph C 21**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

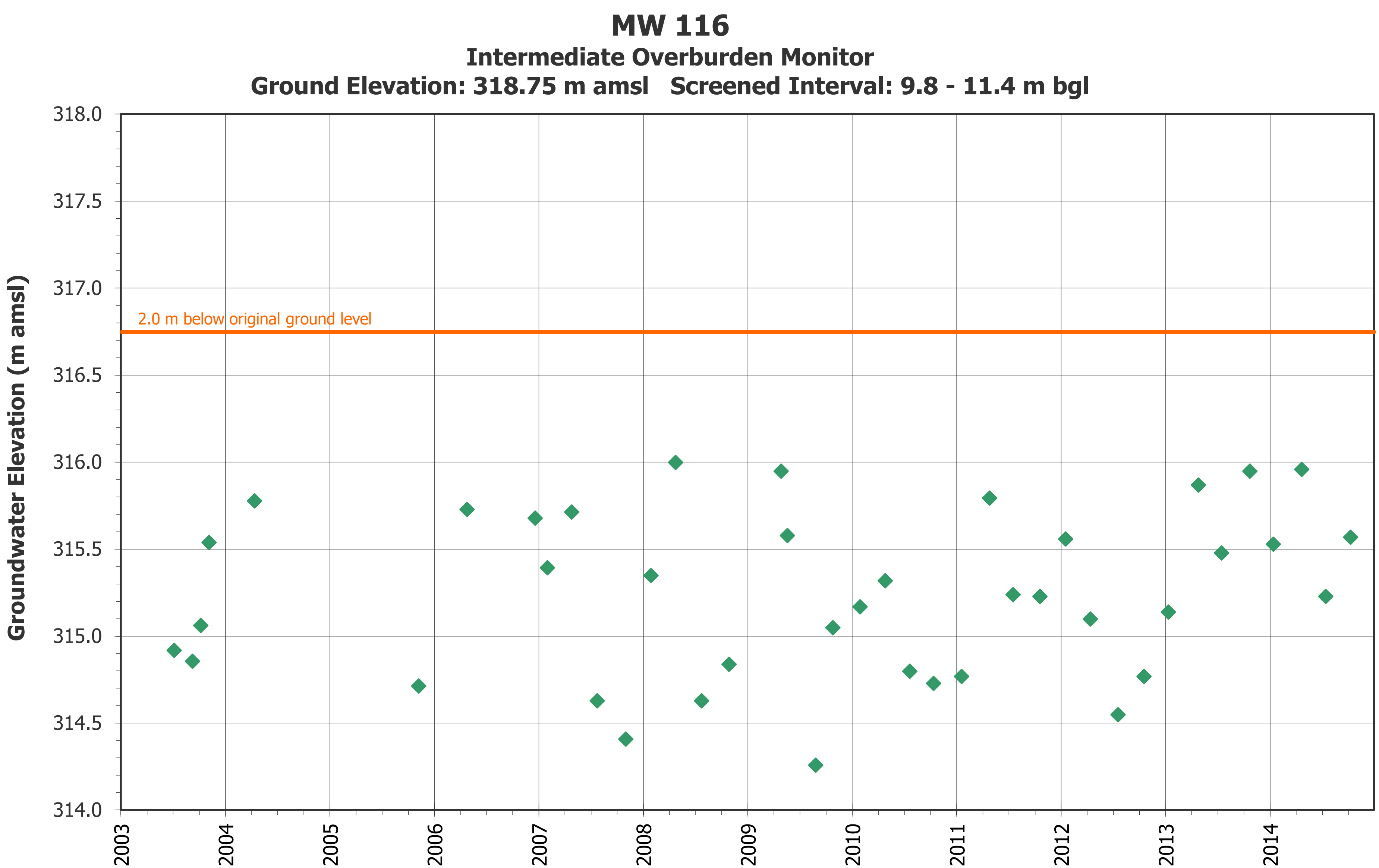
December 2014 **Phase 1 - Core PSW** **Graph C 22**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

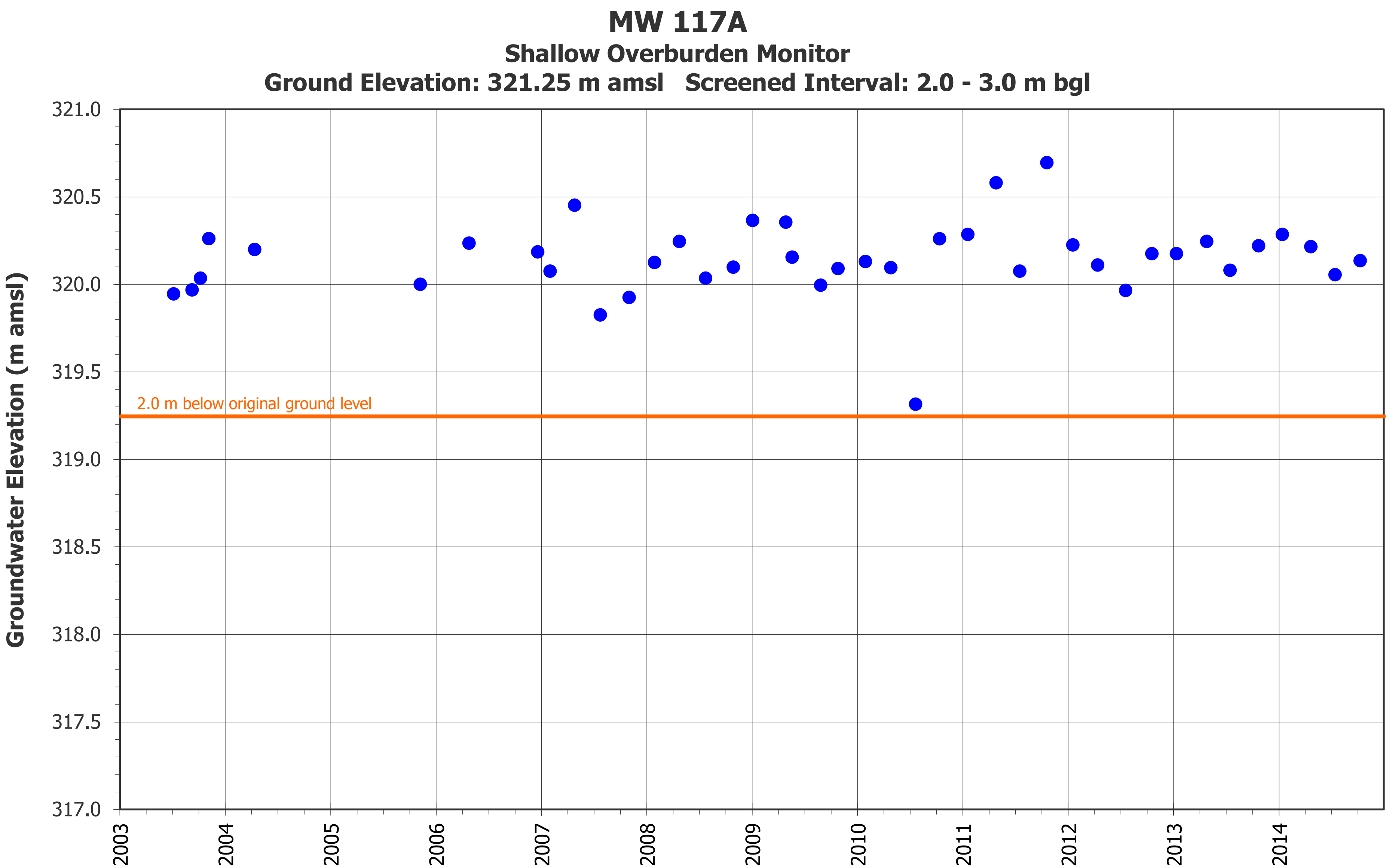
December 2014 **Phase 1 - Core PSW** **Graph C 23**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

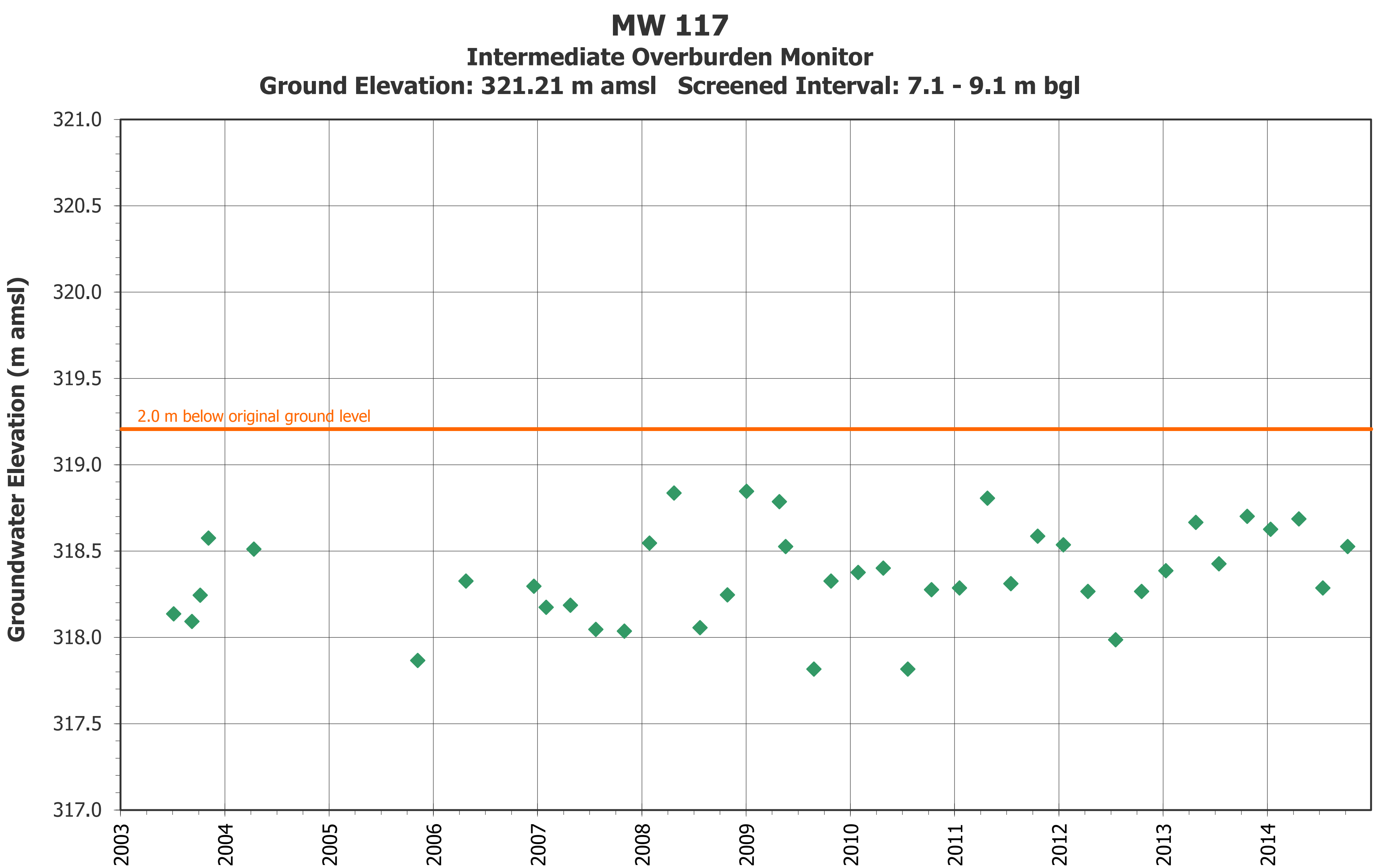
December 2014 **Phase 1 - Core PSW** **Graph C 24**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph C 25**

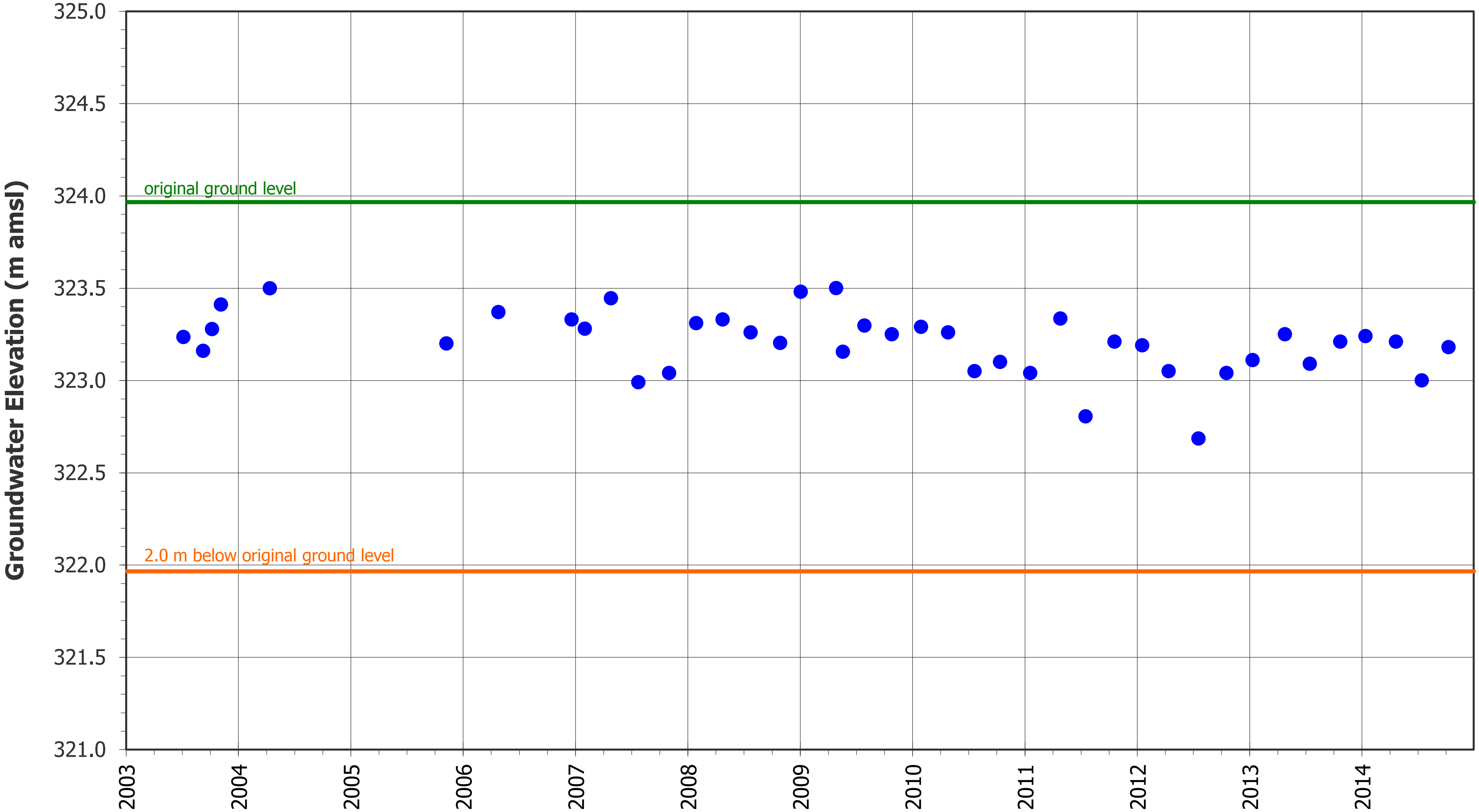


Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph C 26**

MW 118A
Shallow Overburden Monitor
Ground Elevation: 323.97 m amsl   Screened Interval: 2.1 - 4.0 m bgl



Banks Groundwater Engineering Limited

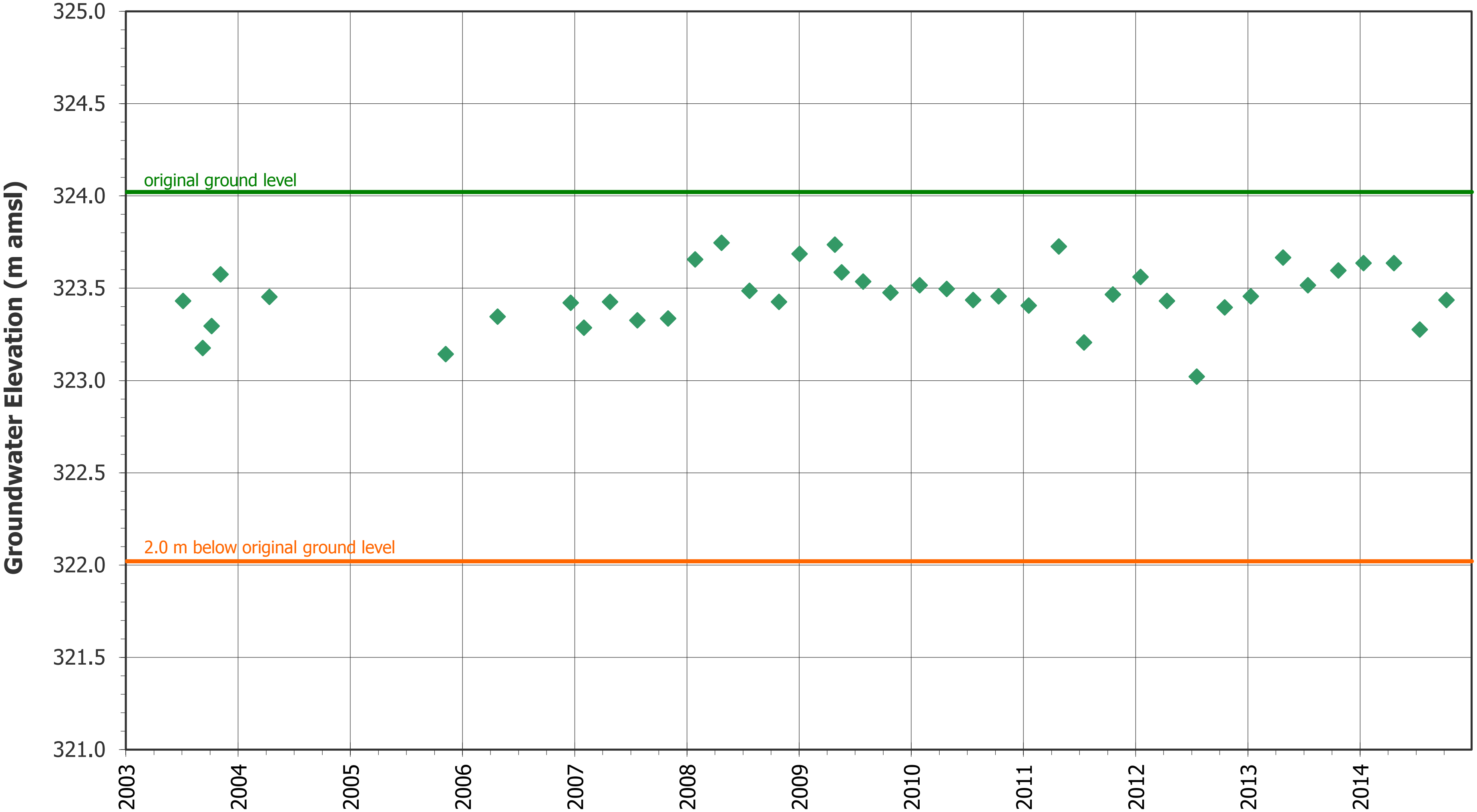
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014   **Phase 1 - Core PSW**   **Graph C 27**

MW 118

Intermediate Overburden Monitor

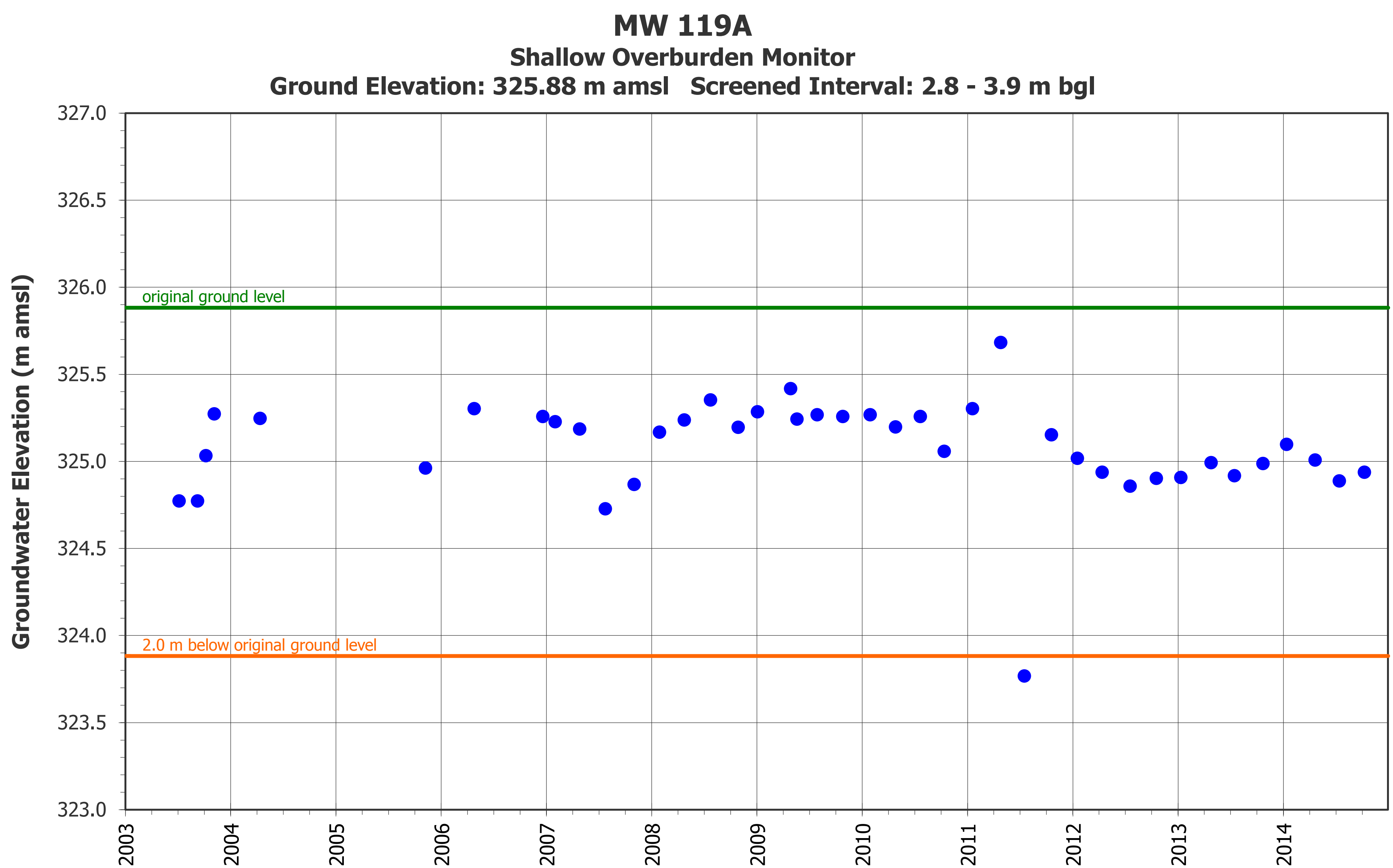
Ground Elevation: 324.02 m amsl   Screened Interval: 7.3 - 9.2 m bgl



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014   **Phase 1 - Core PSW**   **Graph C 28**



Banks Groundwater Engineering Limited

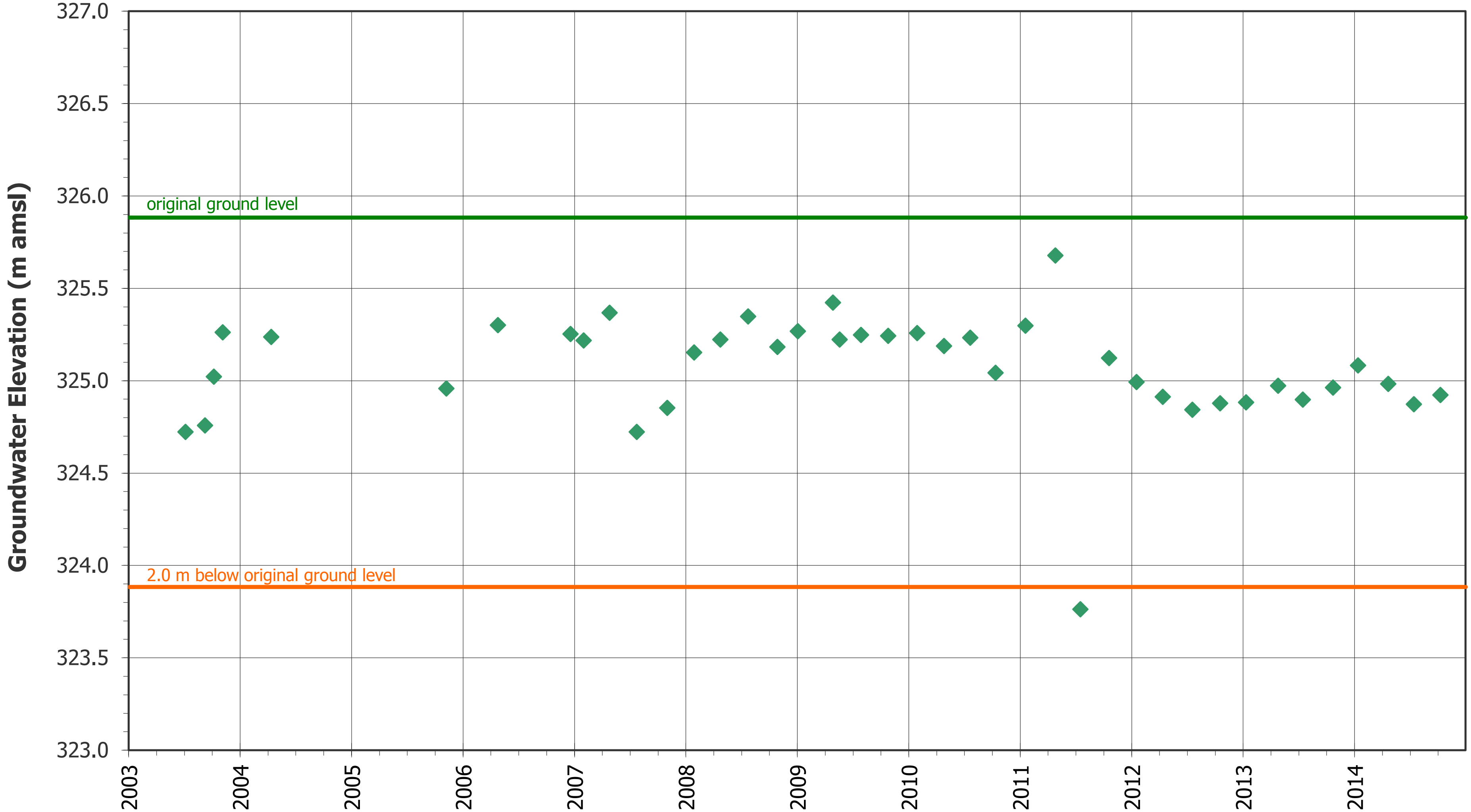
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Core PSW** **Graph C 29**

MW 119

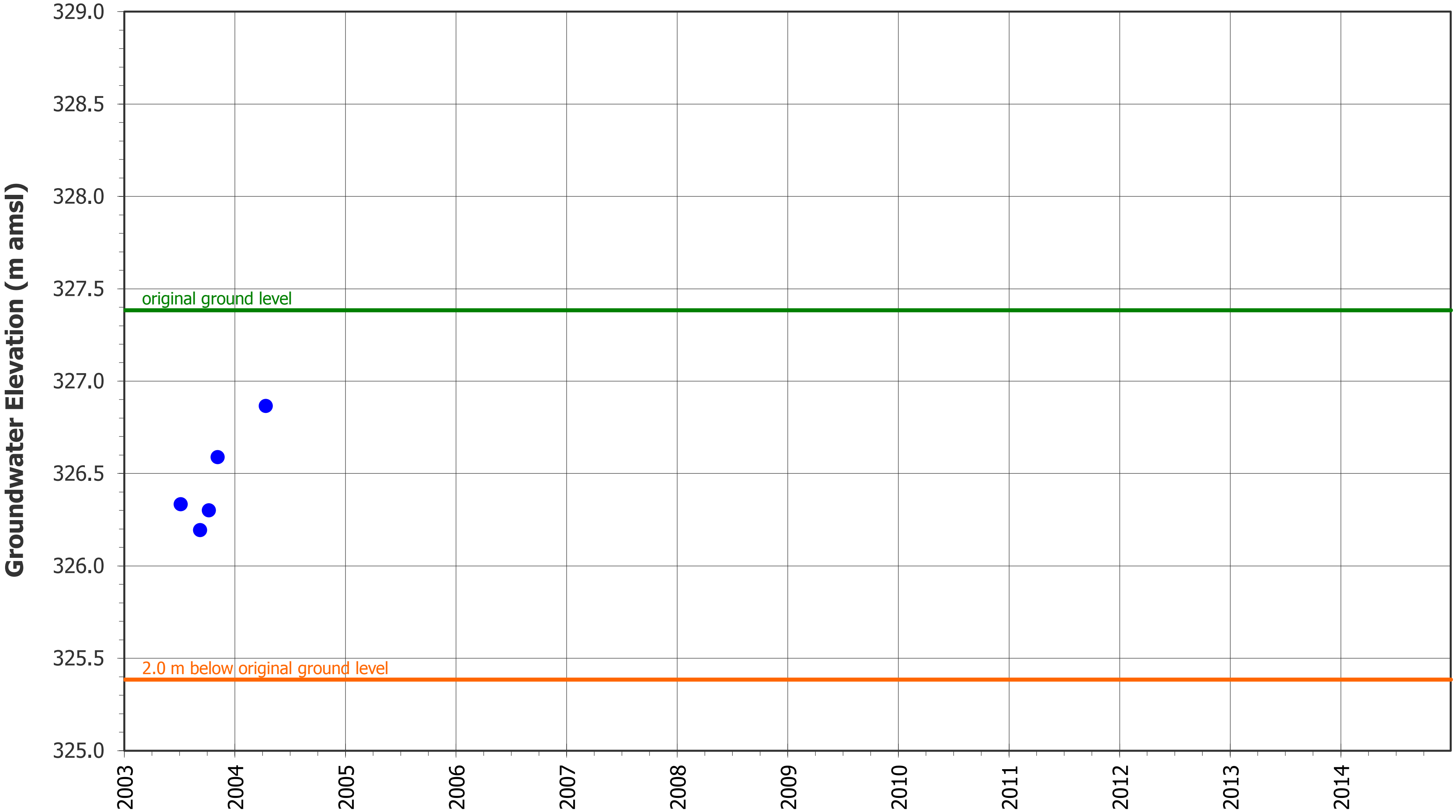
Intermediate Overburden Monitor

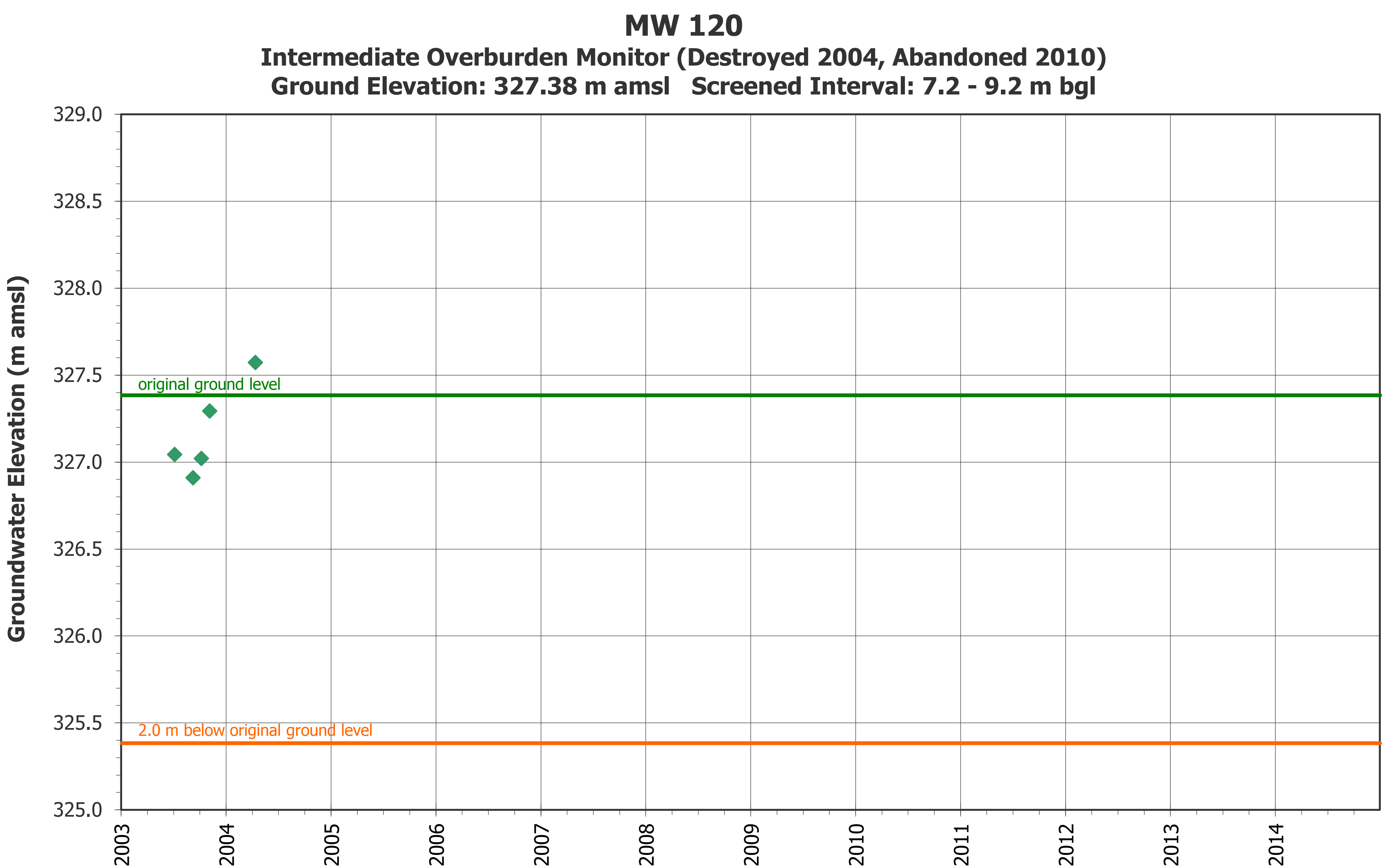
Ground Elevation: 325.88 m amsl   Screened Interval: 6.0 - 8.0 m bgl

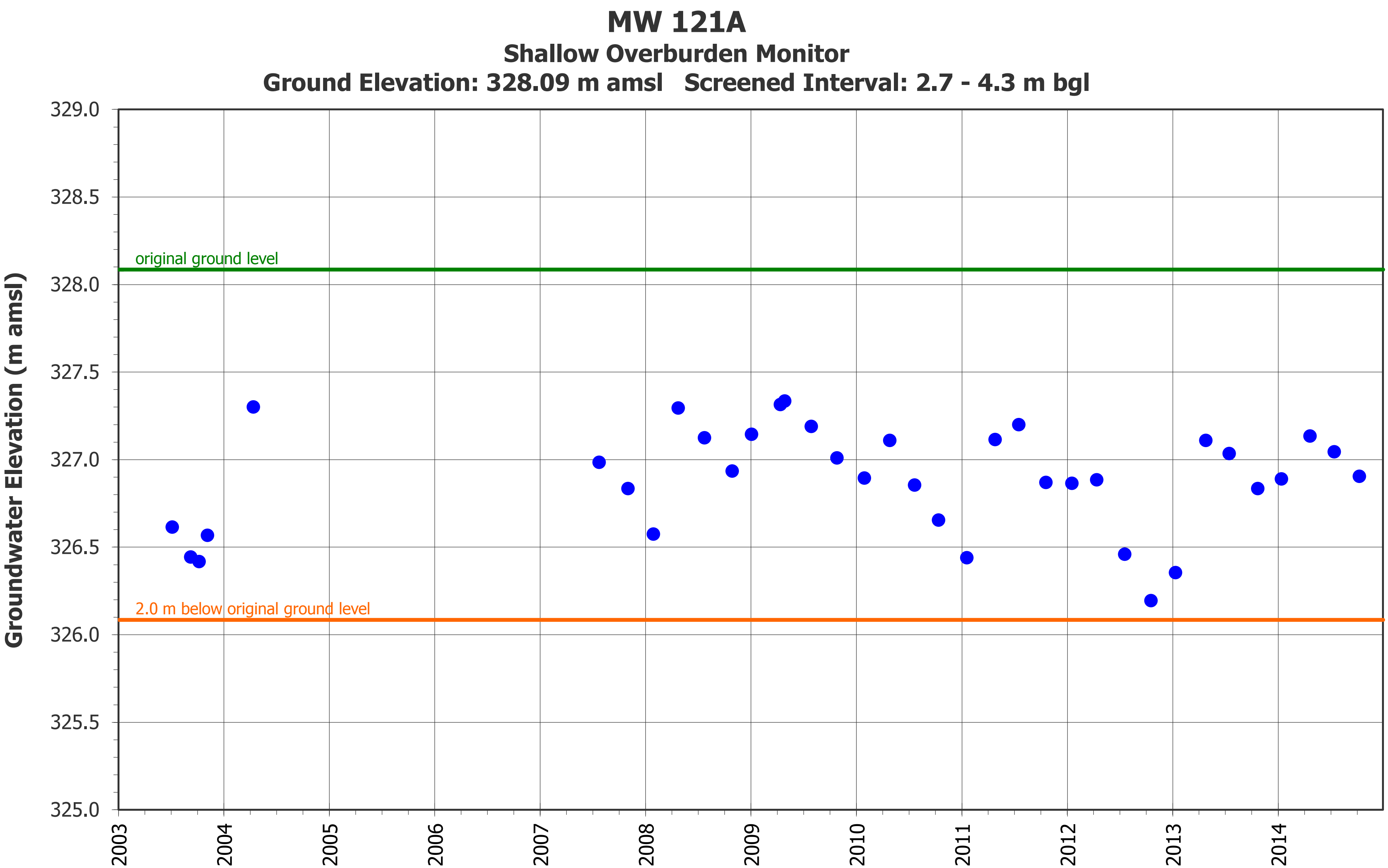


MW 120A

Shallow Overburden Monitor (Destroyed 2004, Abandoned 2010)
Ground Elevation: 327.38 m amsl   Screened Interval: 2.5 - 4.0 m bgl



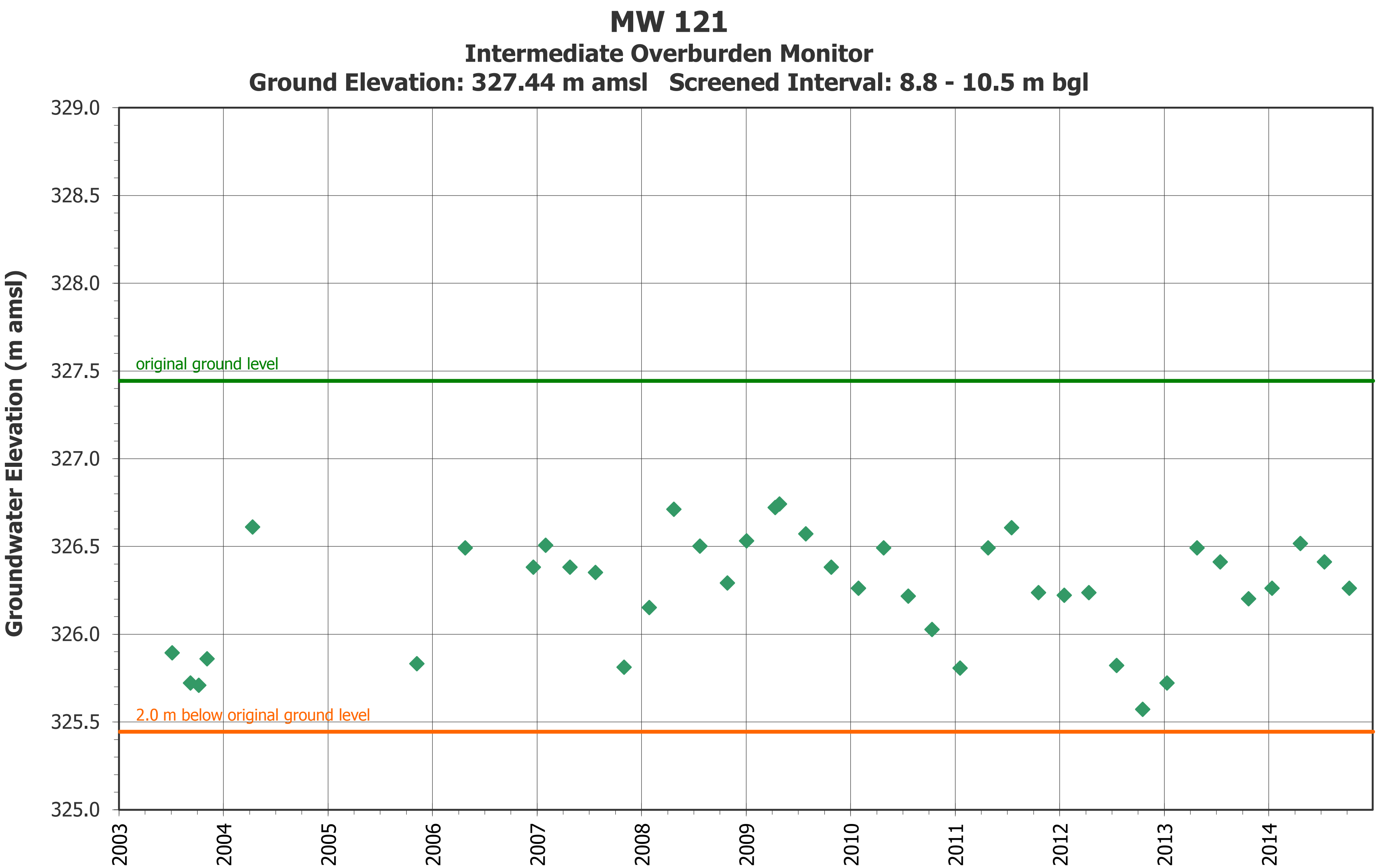

MW 120
Intermediate Overburden Monitor (Destroyed 2004, Abandoned 2010)
Ground Elevation: 327.38 m amsl   Screened Interval: 7.2 - 9.2 m bgl
Groundwater Elevation (m amsl)
329.0
328.5
328.0
327.5
327.0
326.5
326.0
325.5
325.0
original ground level
2.0 m below original ground level
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

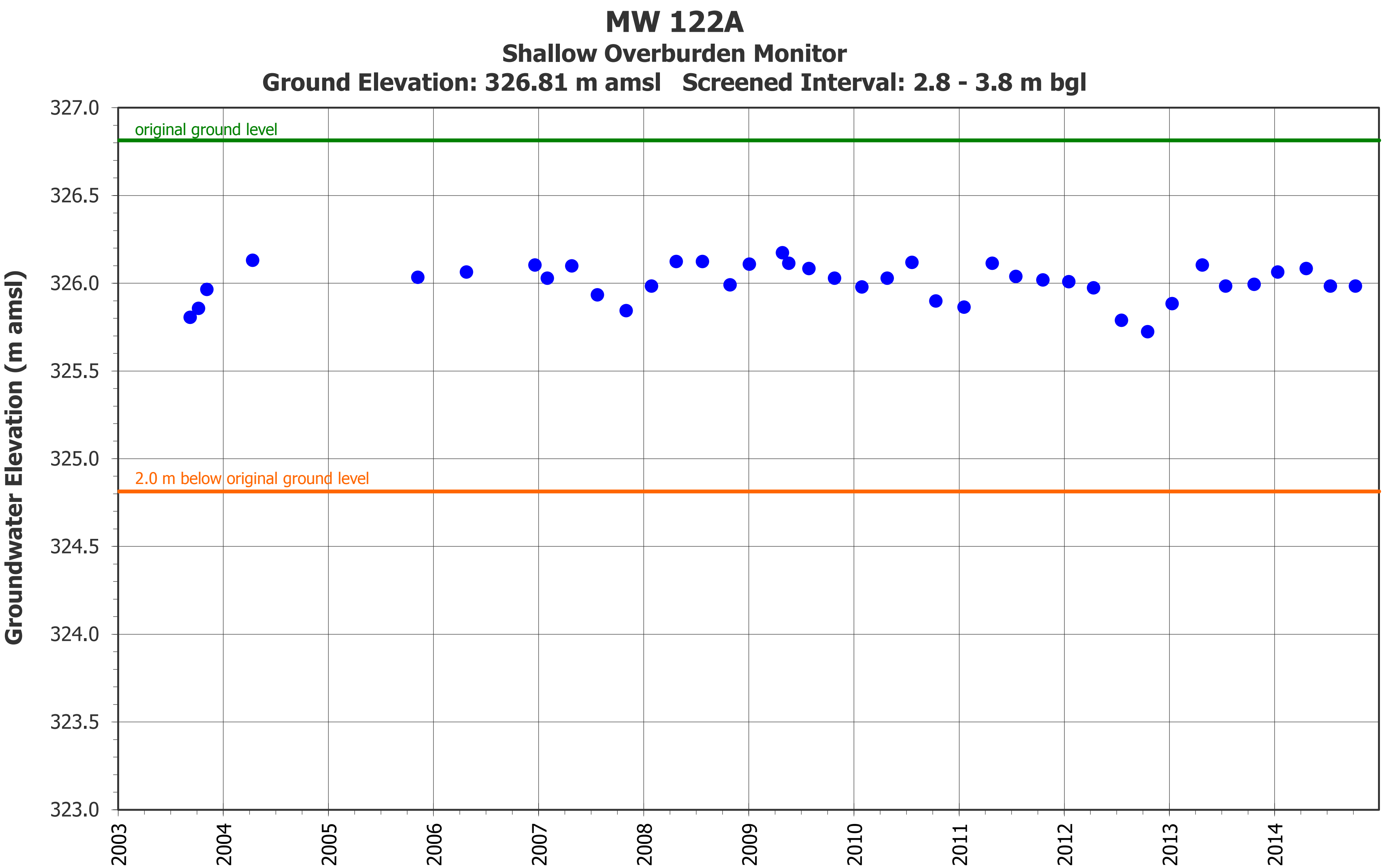
December 2014 **Phase 2 - Core PSW** **Graph C 33**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Core PSW** **Graph C 34**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

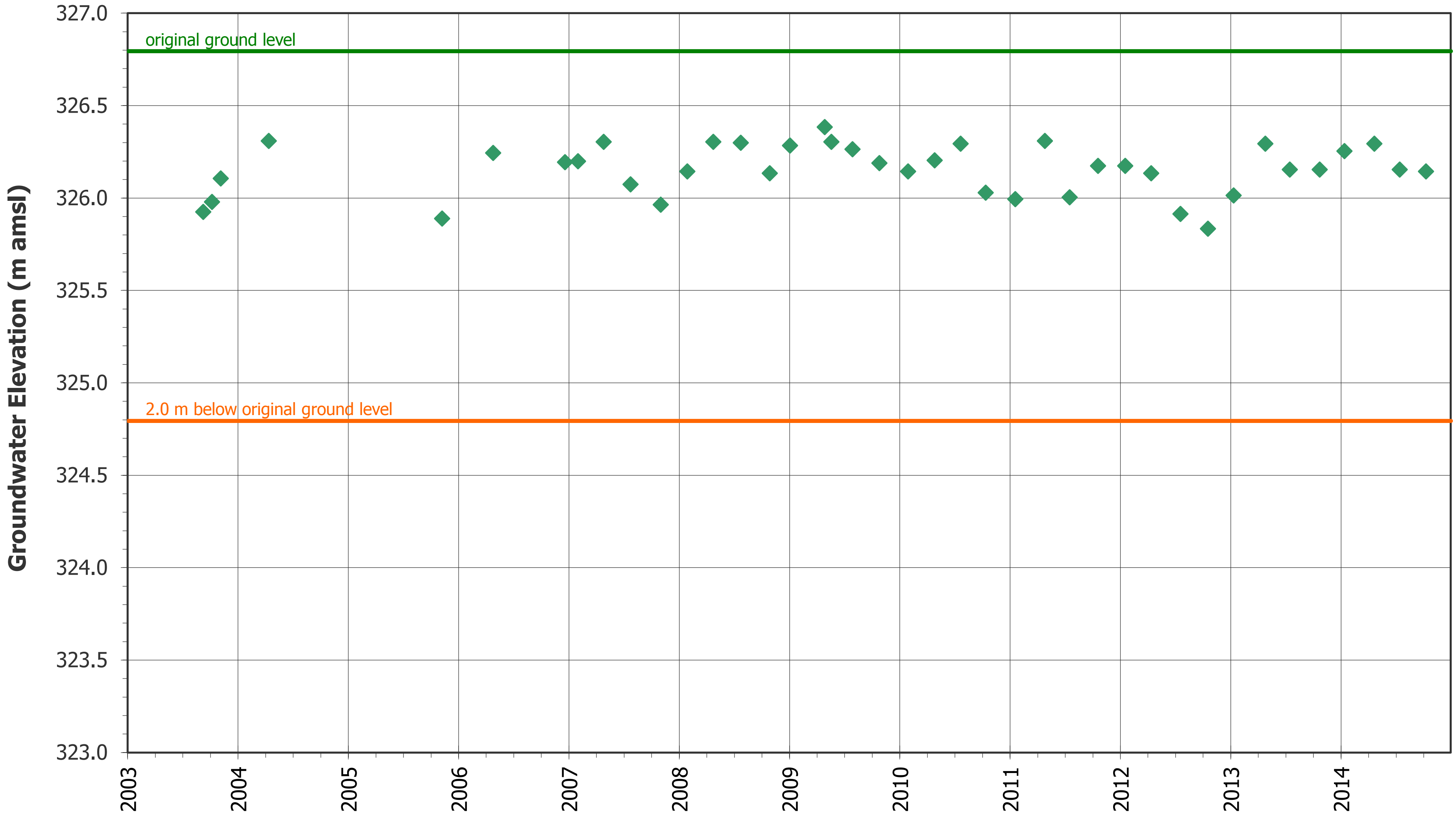
December 2014

Phase 3 - Core PSW   Graph C 35

MW 122

Intermediate Overburden Monitor

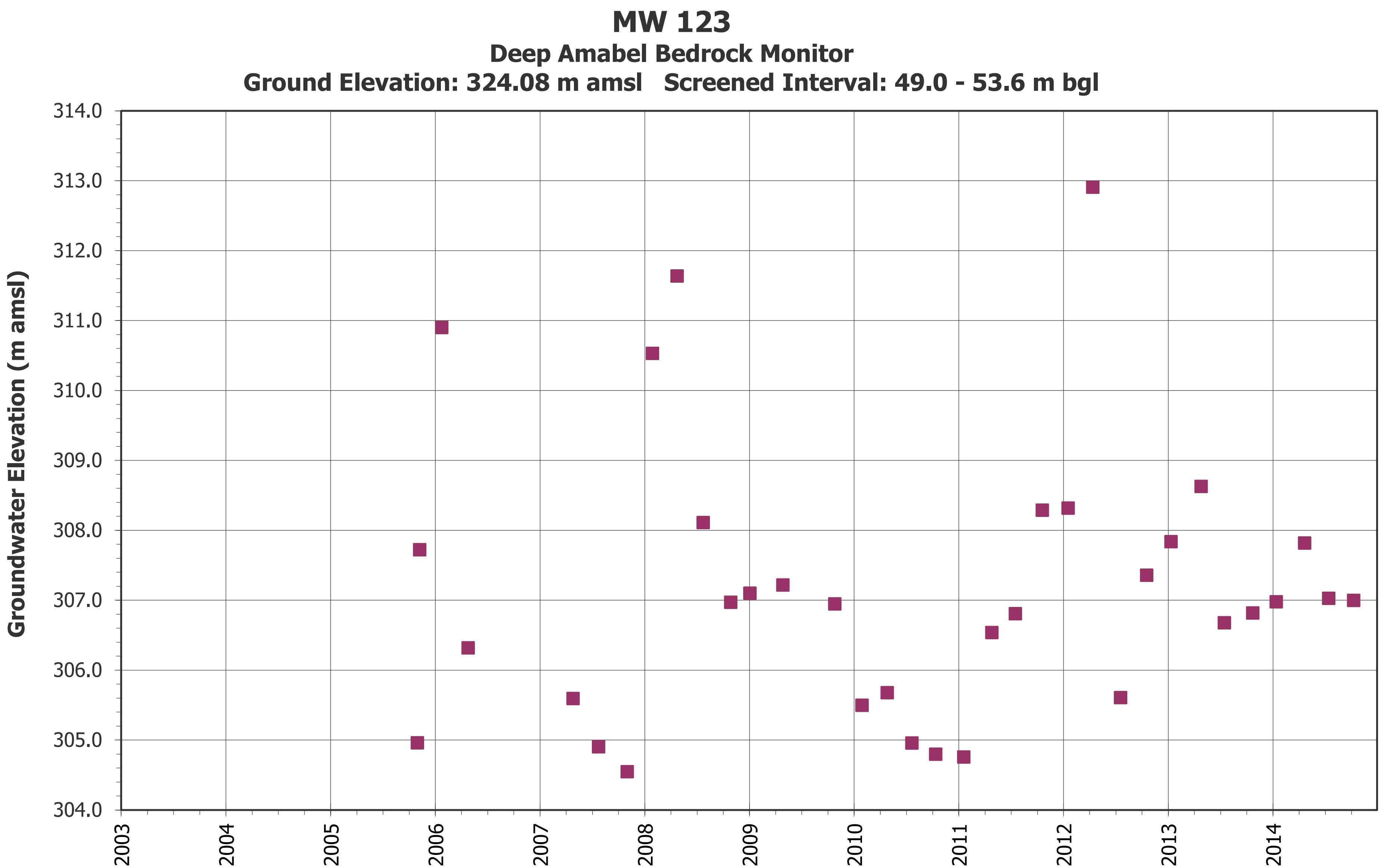
Ground Elevation: 326.79 m amsl   Screened Interval: 5.8 - 7.6 m bgl



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

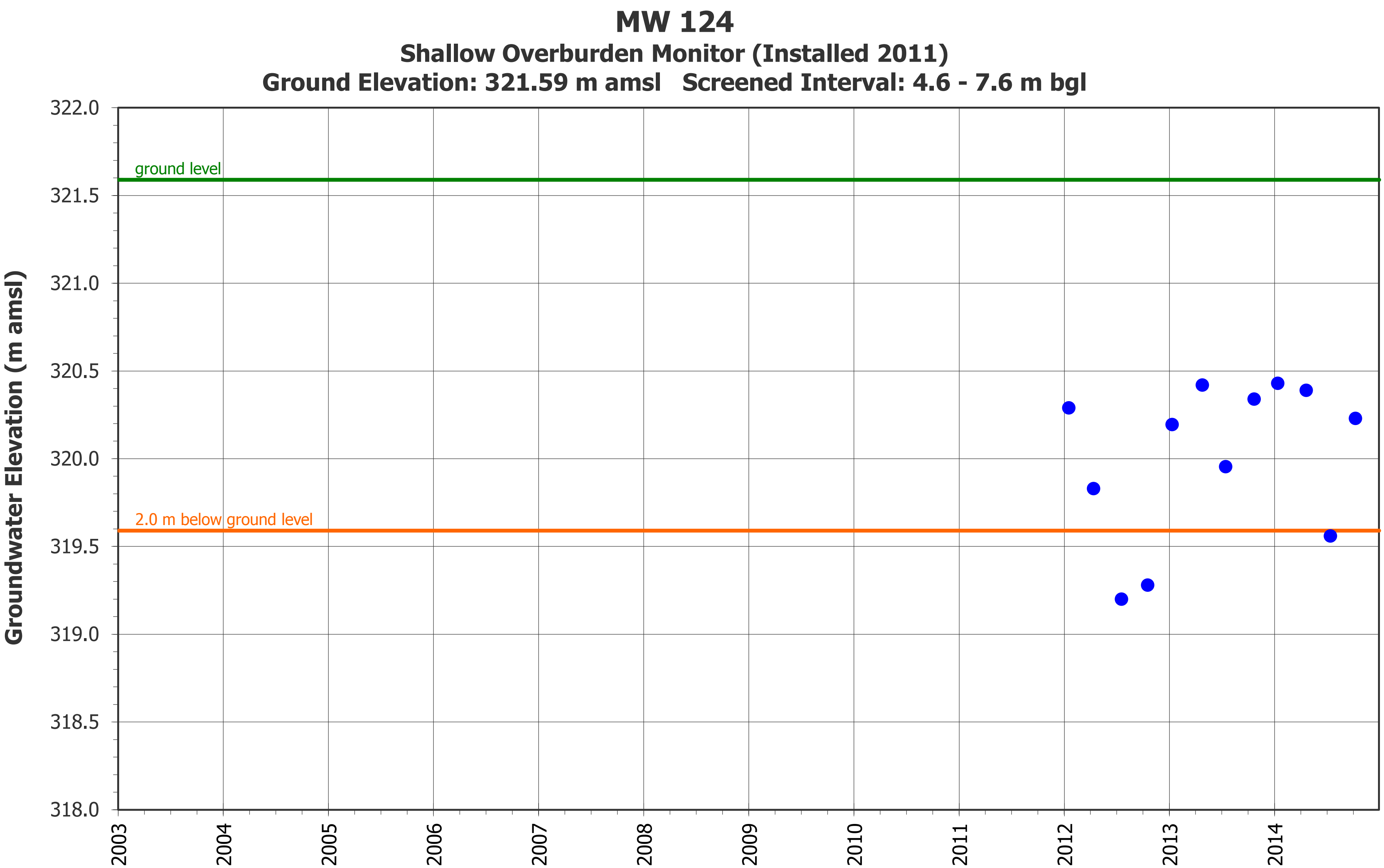
December 2014   **Phase 3 - Core PSW**   **Graph C 36**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

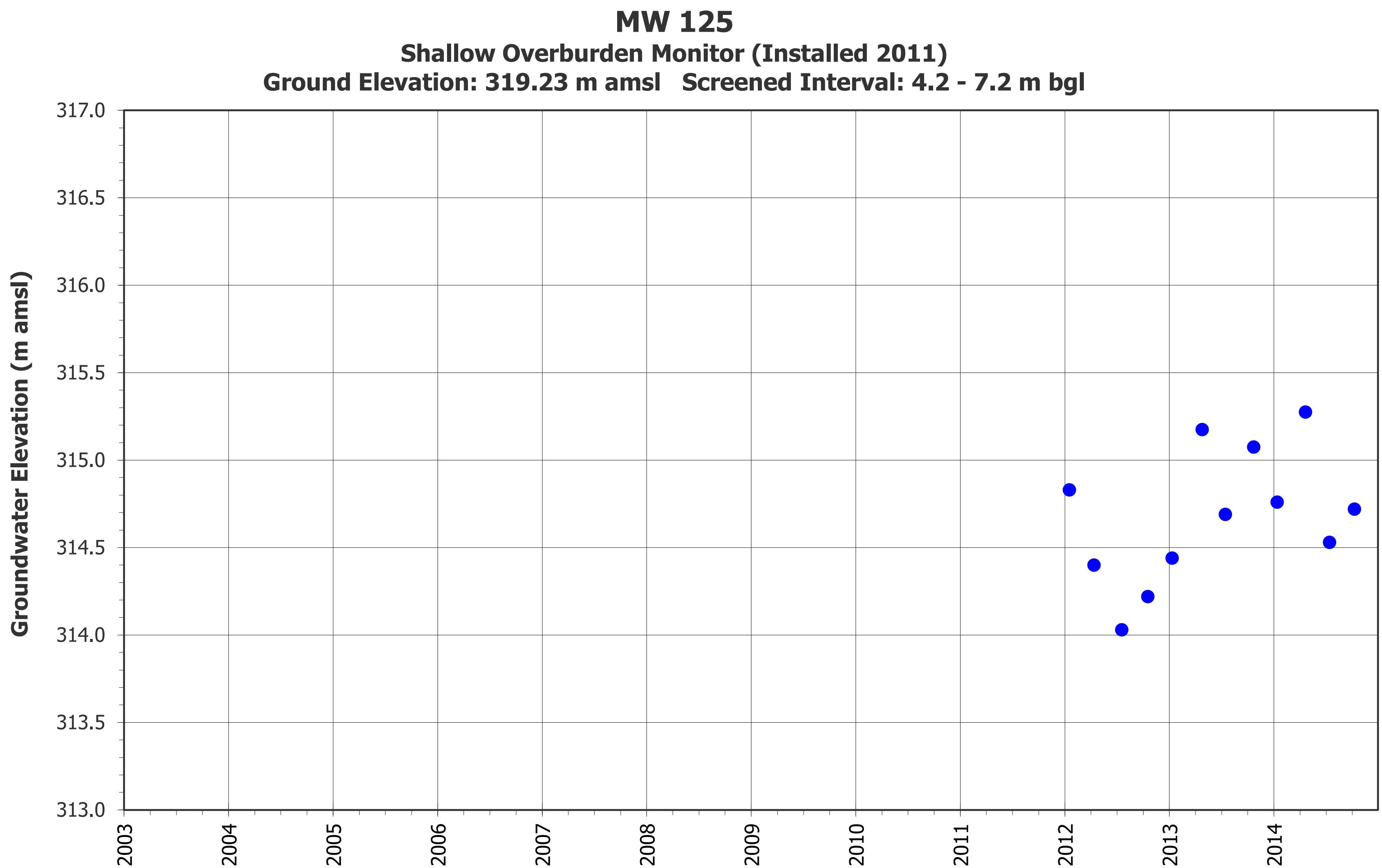
December 2014 **Phase 1 - Core PSW** **Graph C 37**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

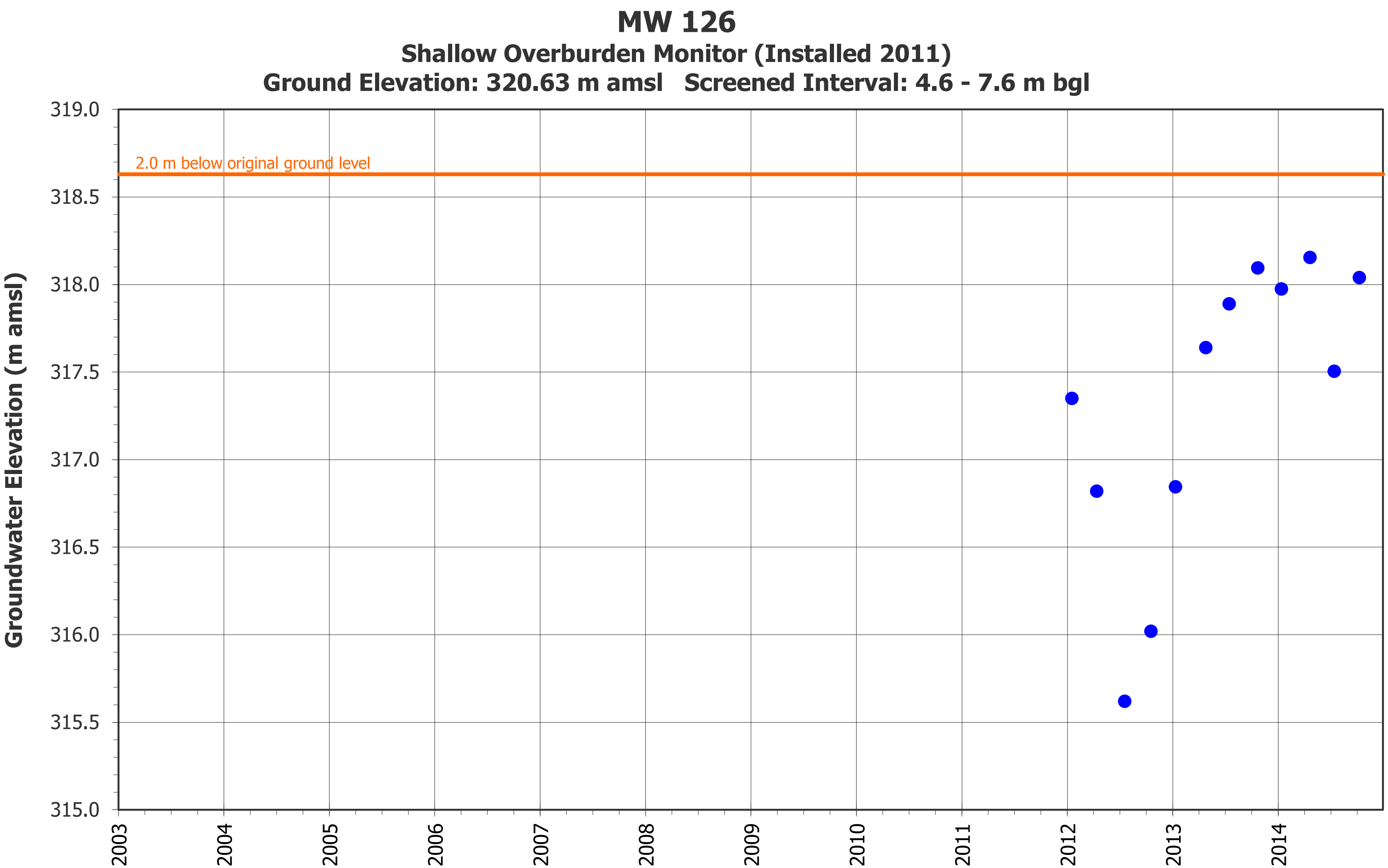
December 2014 **Phase 1 - Perimeter** **Graph C 38**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

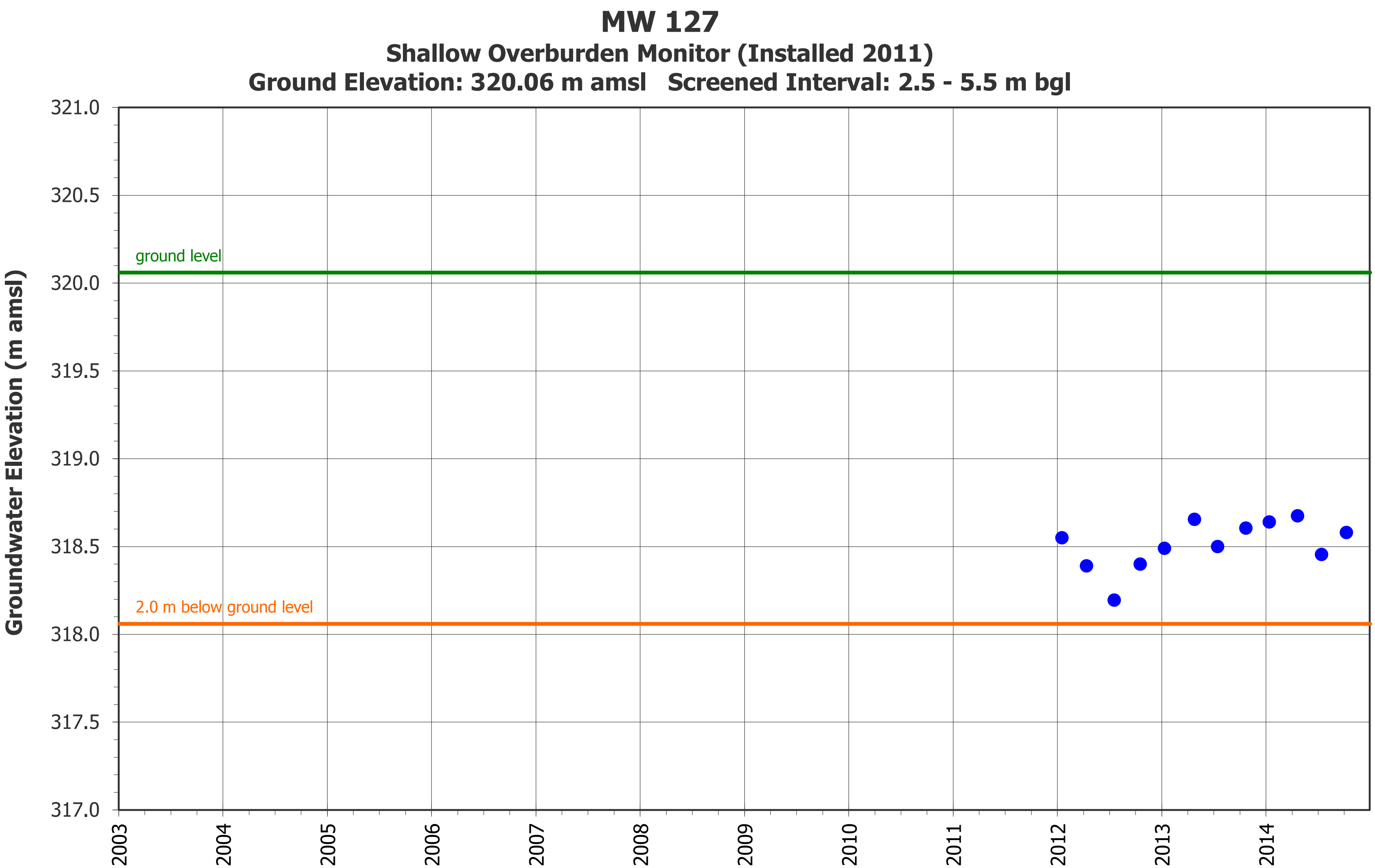
December 2014 **Phase 1 - Perimeter** **Graph C 39**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

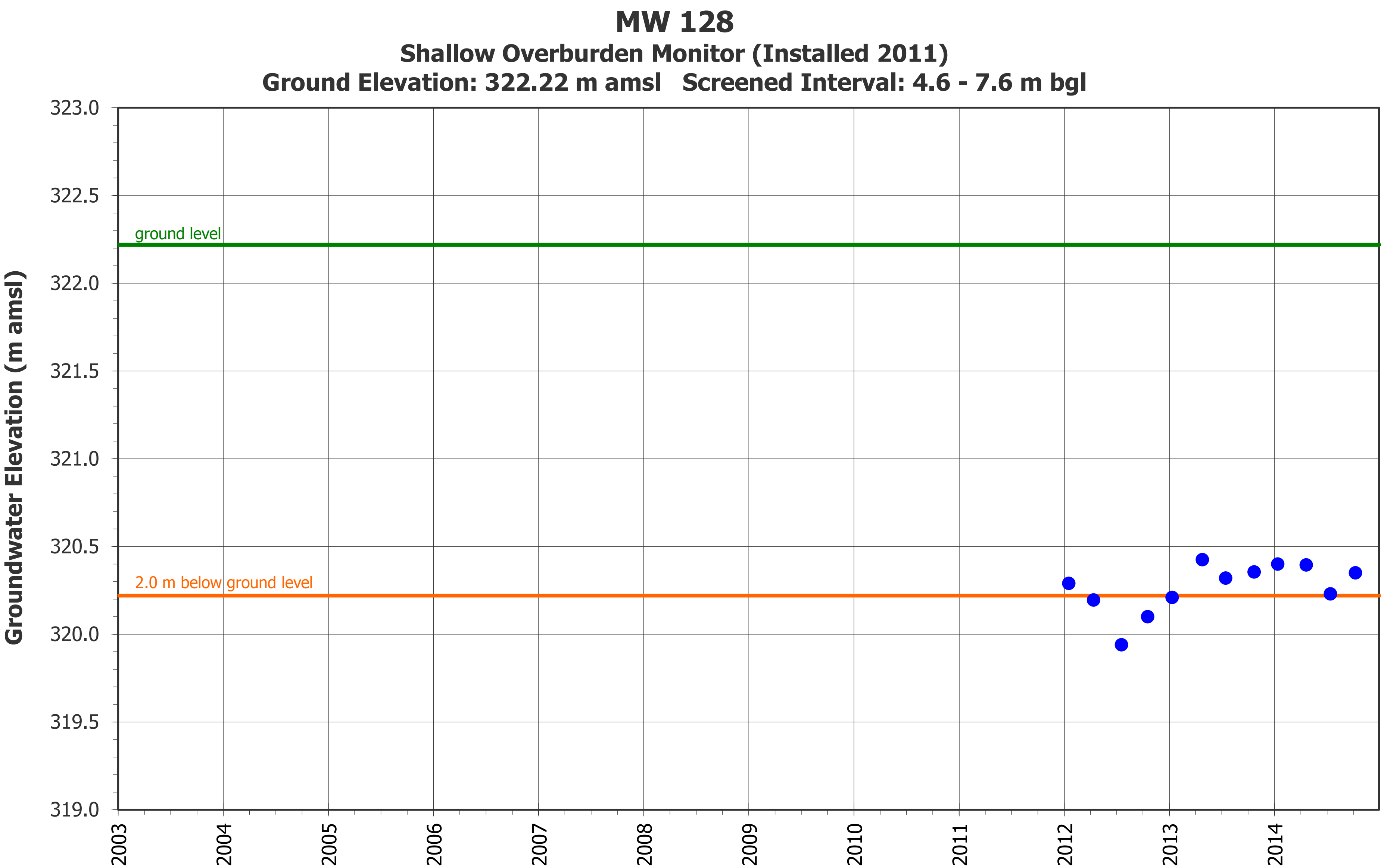
December 2014 **Phase 1 - Perimeter** **Graph C 40**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

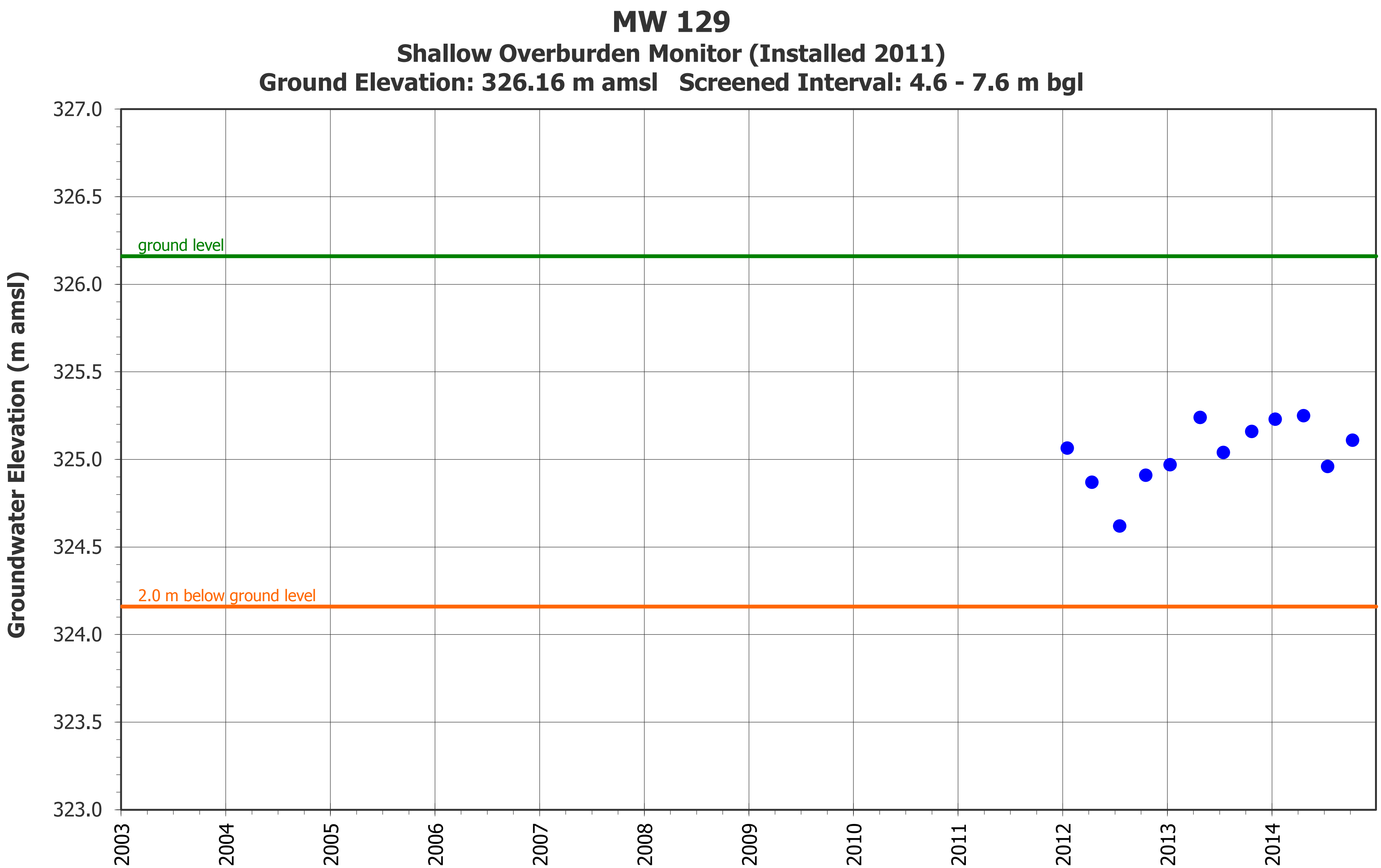
December 2014 **Phase 1 - Core PSW** **Graph C 41**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Perimeter** **Graph C 42**



Banks Groundwater Engineering Limited

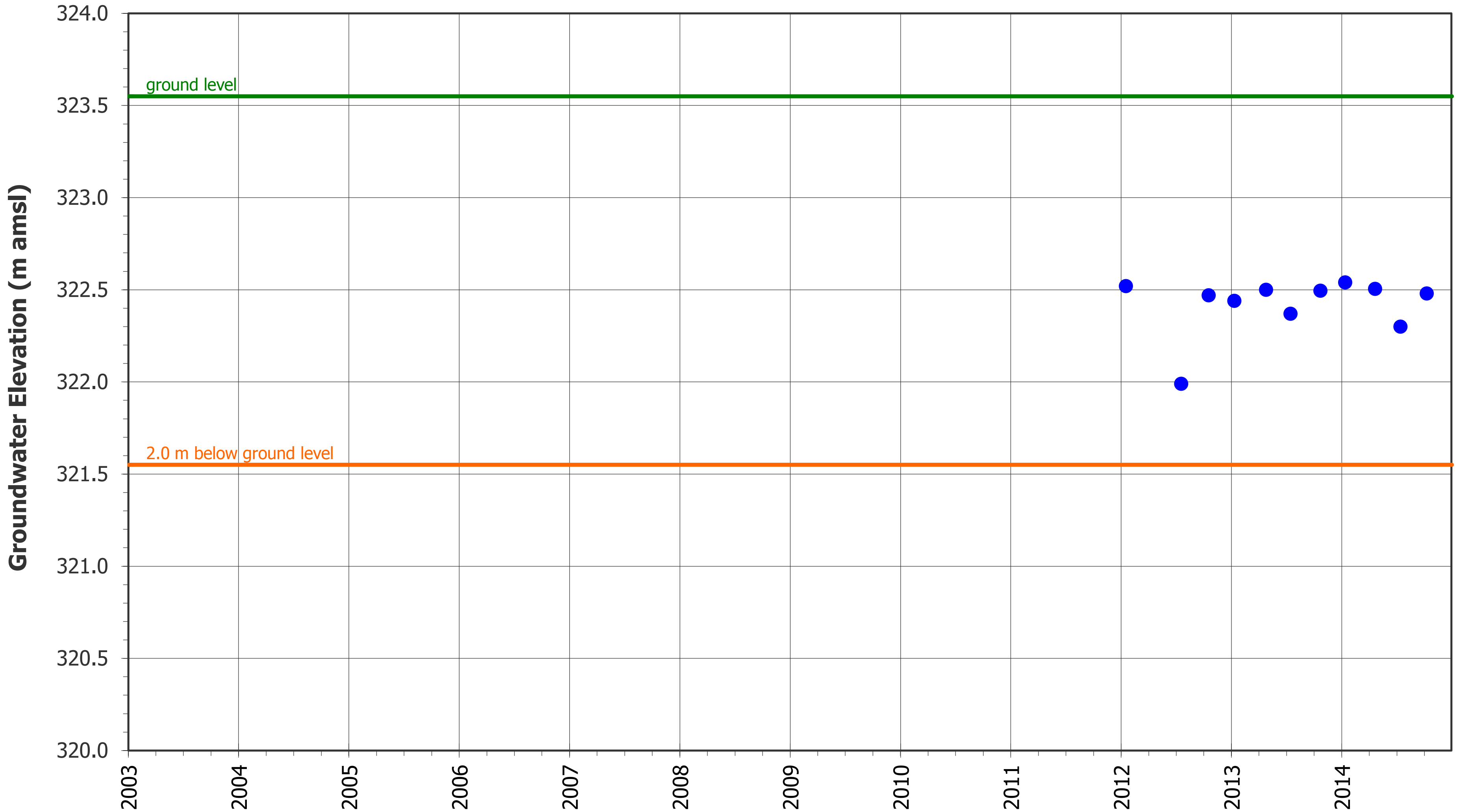
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph C 43**

MW 130

Shallow Overburden Monitor

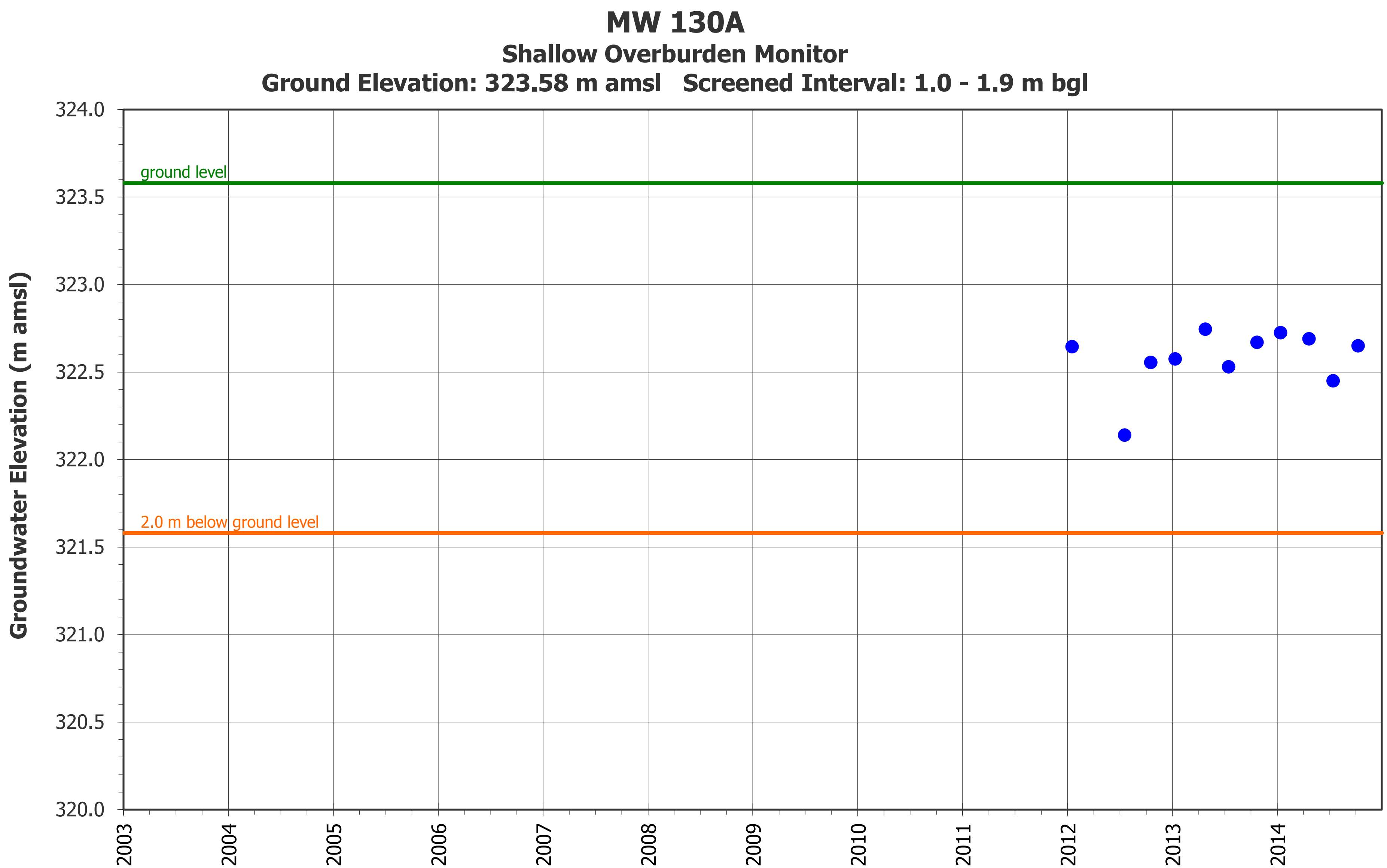
Ground Elevation: 323.55 m amsl   Screened Interval: 2.0 - 3.0 m bgl

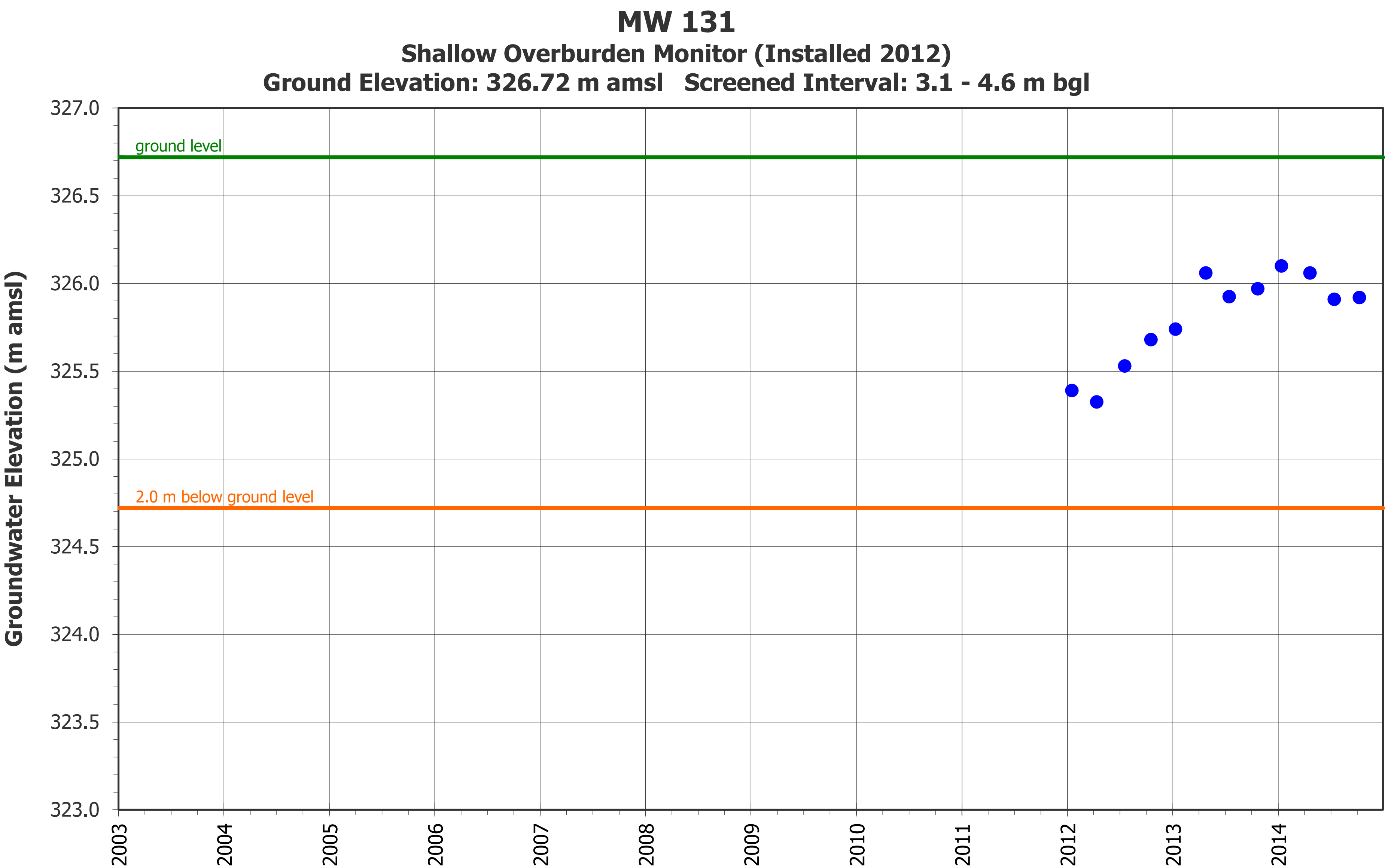


Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph C 44**

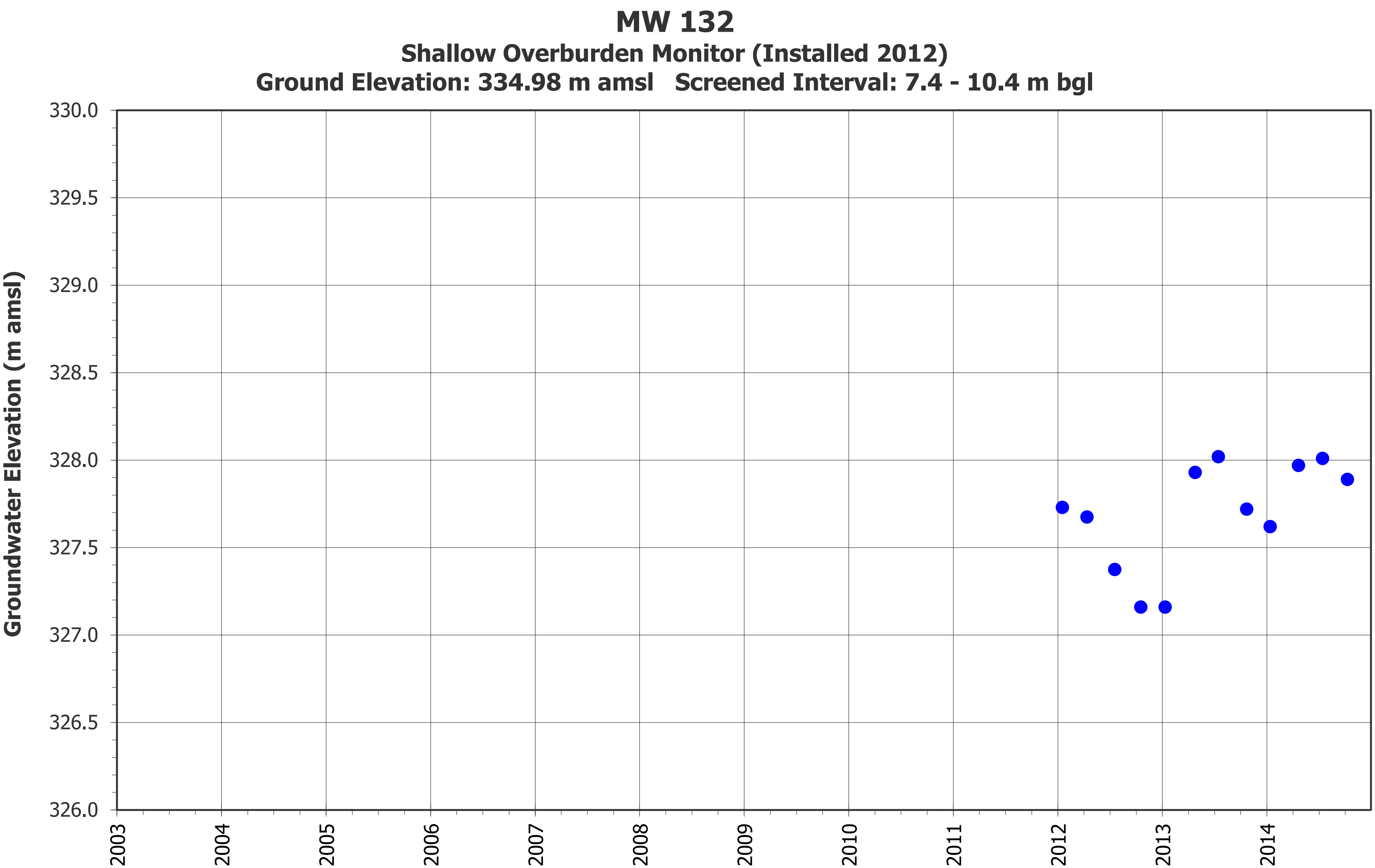

MW 130A
Shallow Overburden Monitor
Ground Elevation: 323.58 m amsl   Screened Interval: 1.0 - 1.9 m bgl
Groundwater Elevation (m amsl)
324.0
323.5
323.0
322.5
322.0
321.5
321.0
320.5
320.0
ground level
2.0 m below ground level
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Core PSW** **Graph C 46**



Banks Groundwater Engineering Limited

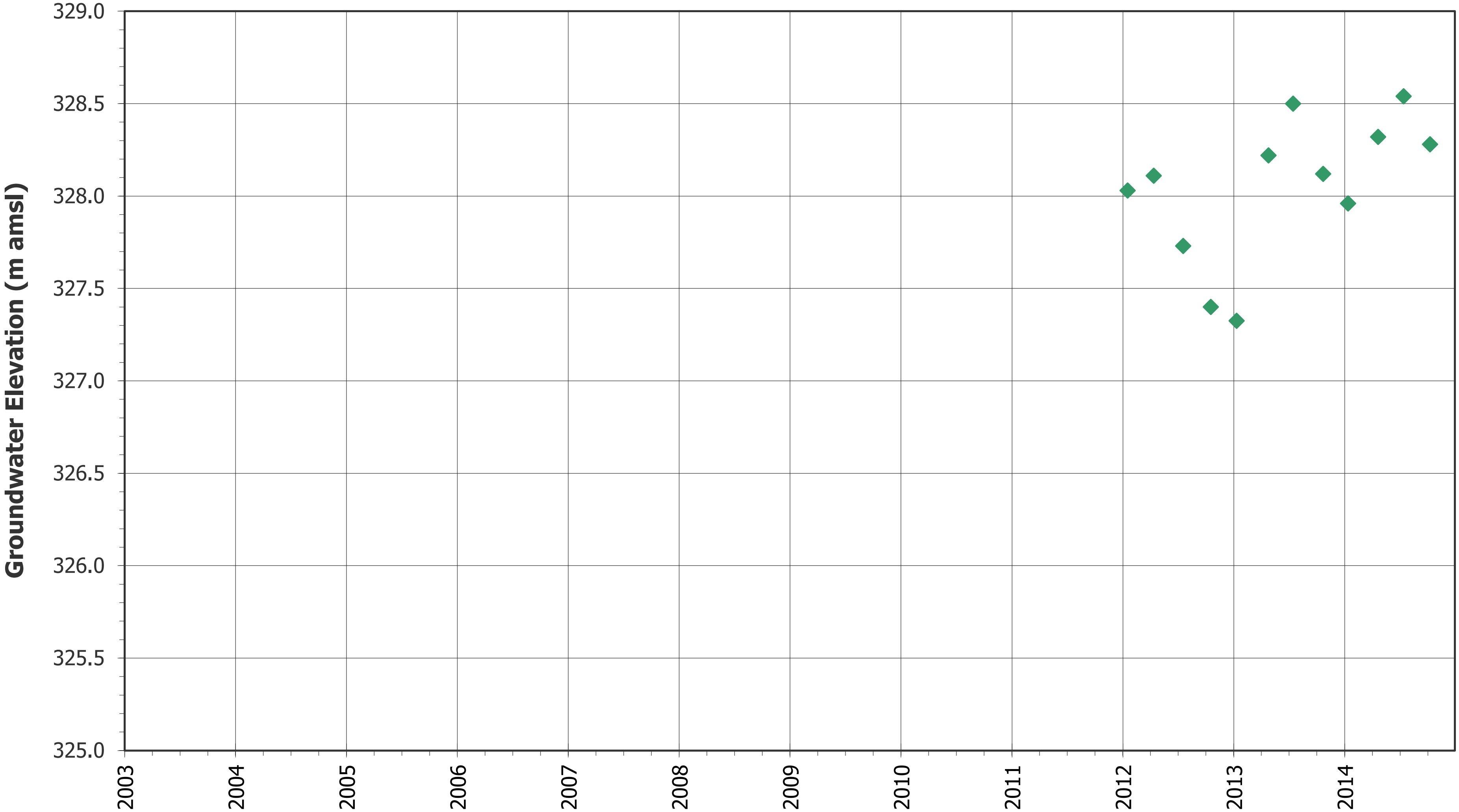
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Perimeter** **Graph C 47**

MW 133

Intermediate Overburden Monitor (Installed 2012)

Ground Elevation: 340.08 m amsl   Screened Interval: 12.5 - 15.5 m bgl



Banks Groundwater Engineering Limited

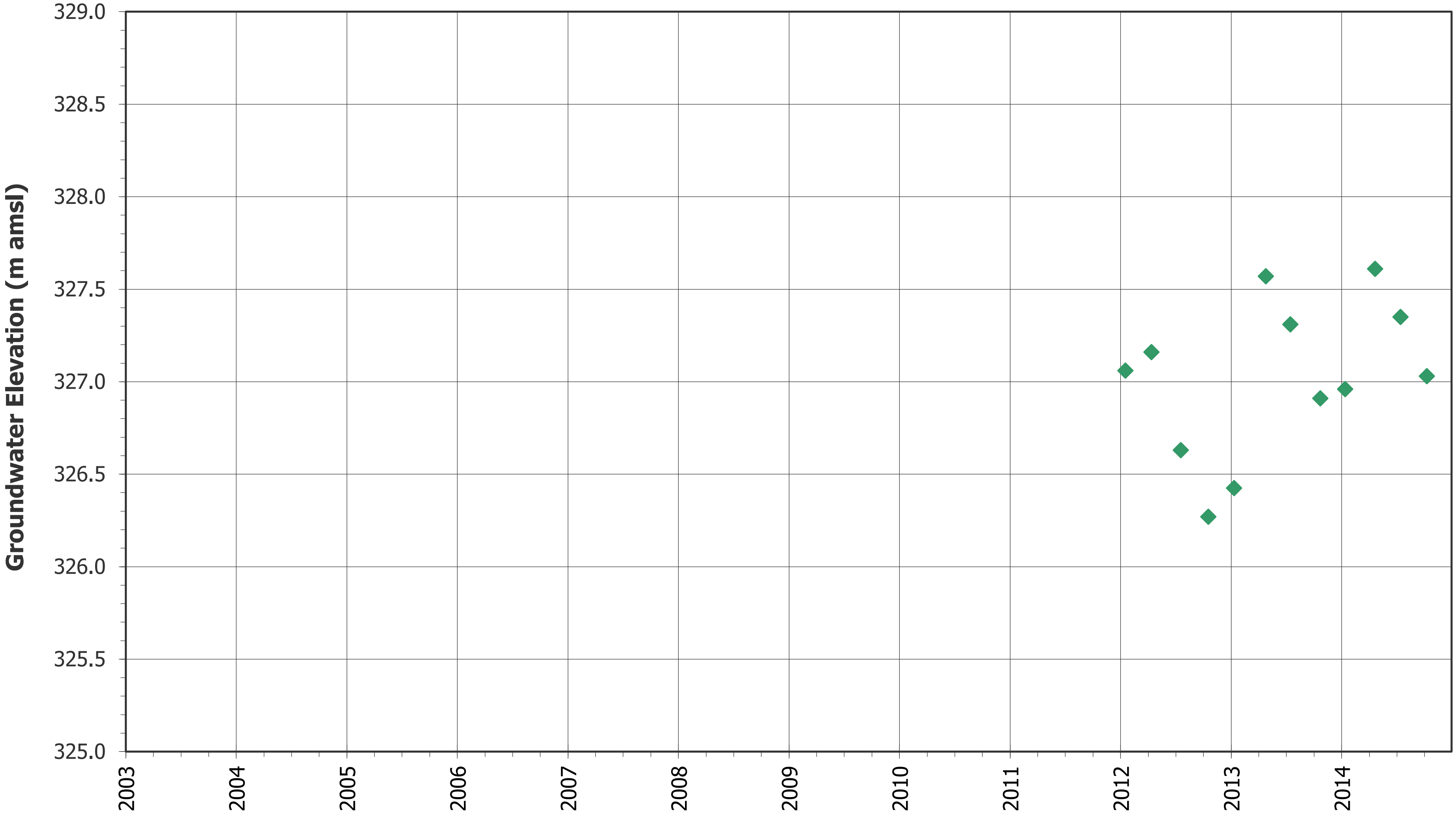
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014   **Phase 2 - Perimeter**   **Graph C 48**

MW 134

Intermediate Overburden Monitor (Installed 2012)

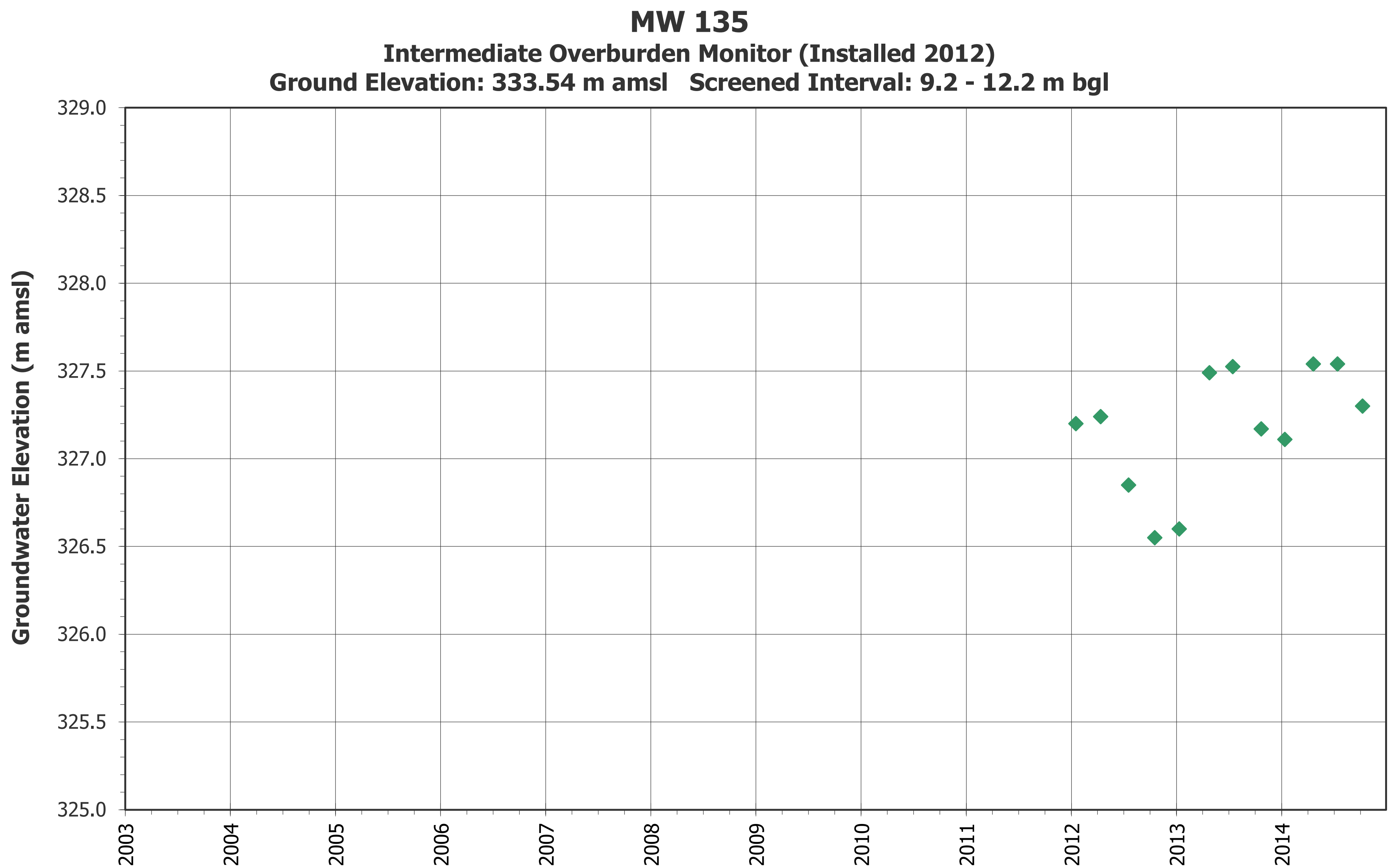
Ground Elevation: 341.46 m amsl   Screened Interval: 14.8 - 17.8 m bgl



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

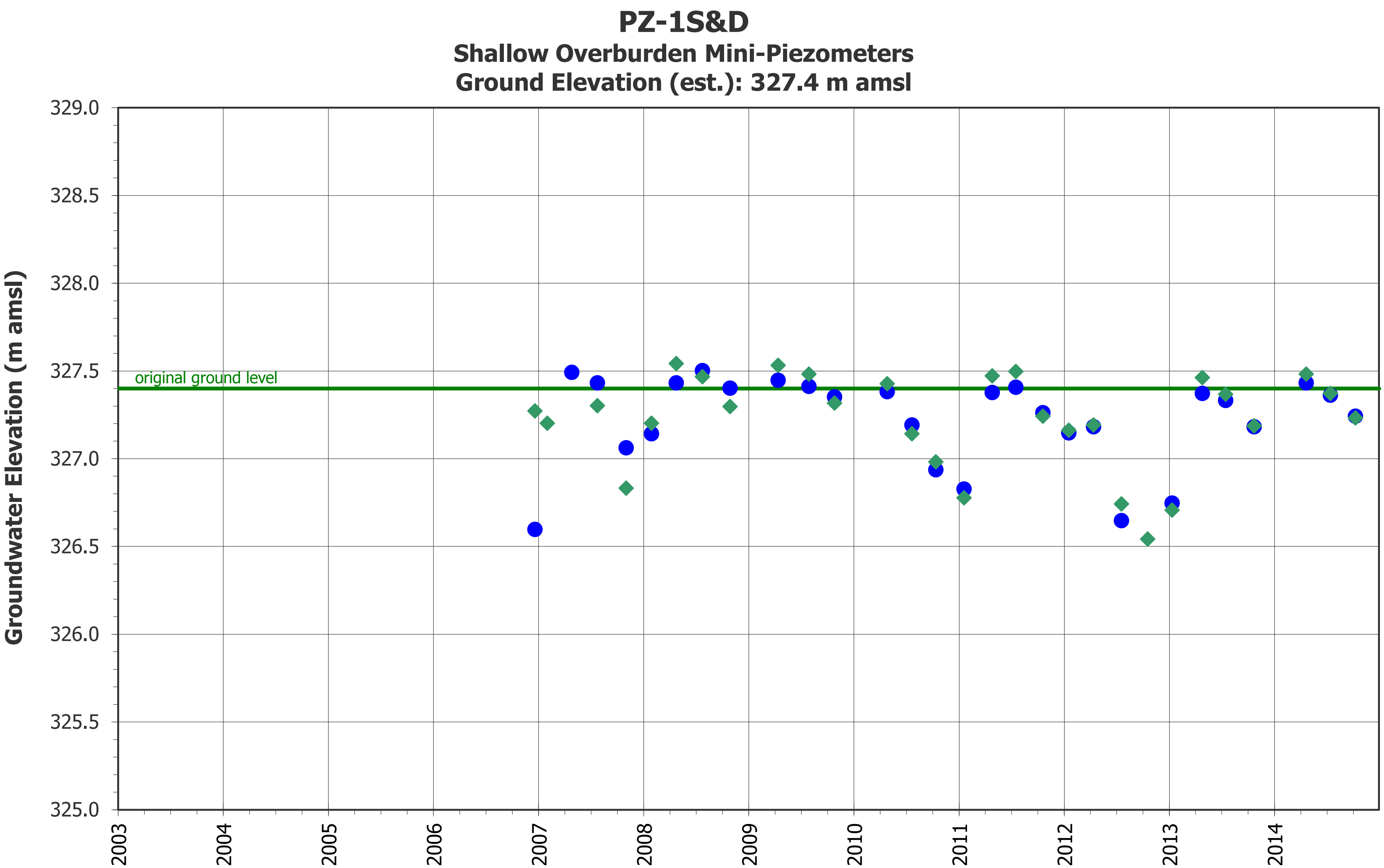
December 2014 **Phase 2 - Perimeter** **Graph C 49**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

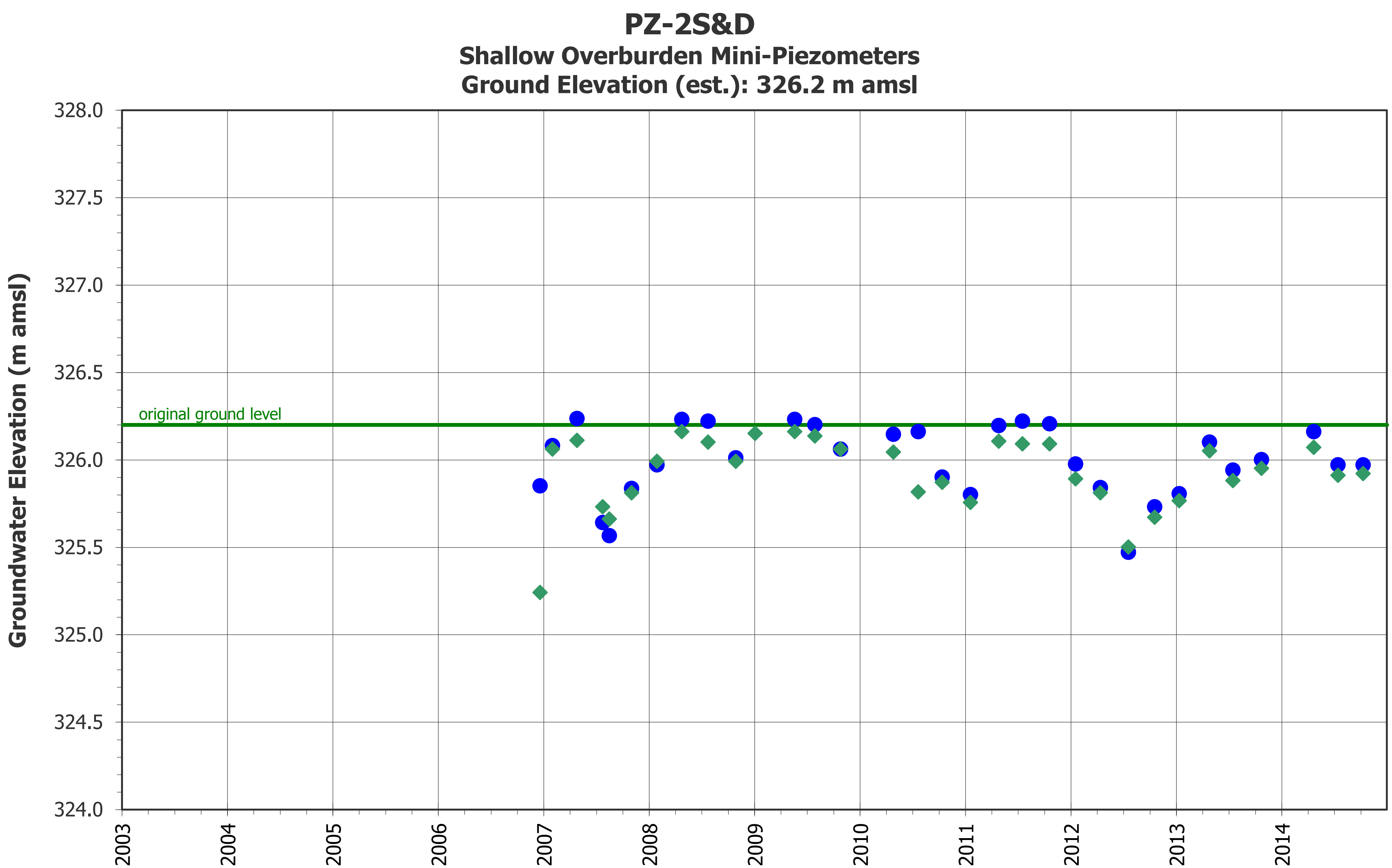
December 2014 **Phase 2 - Perimeter** **Graph C 50**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

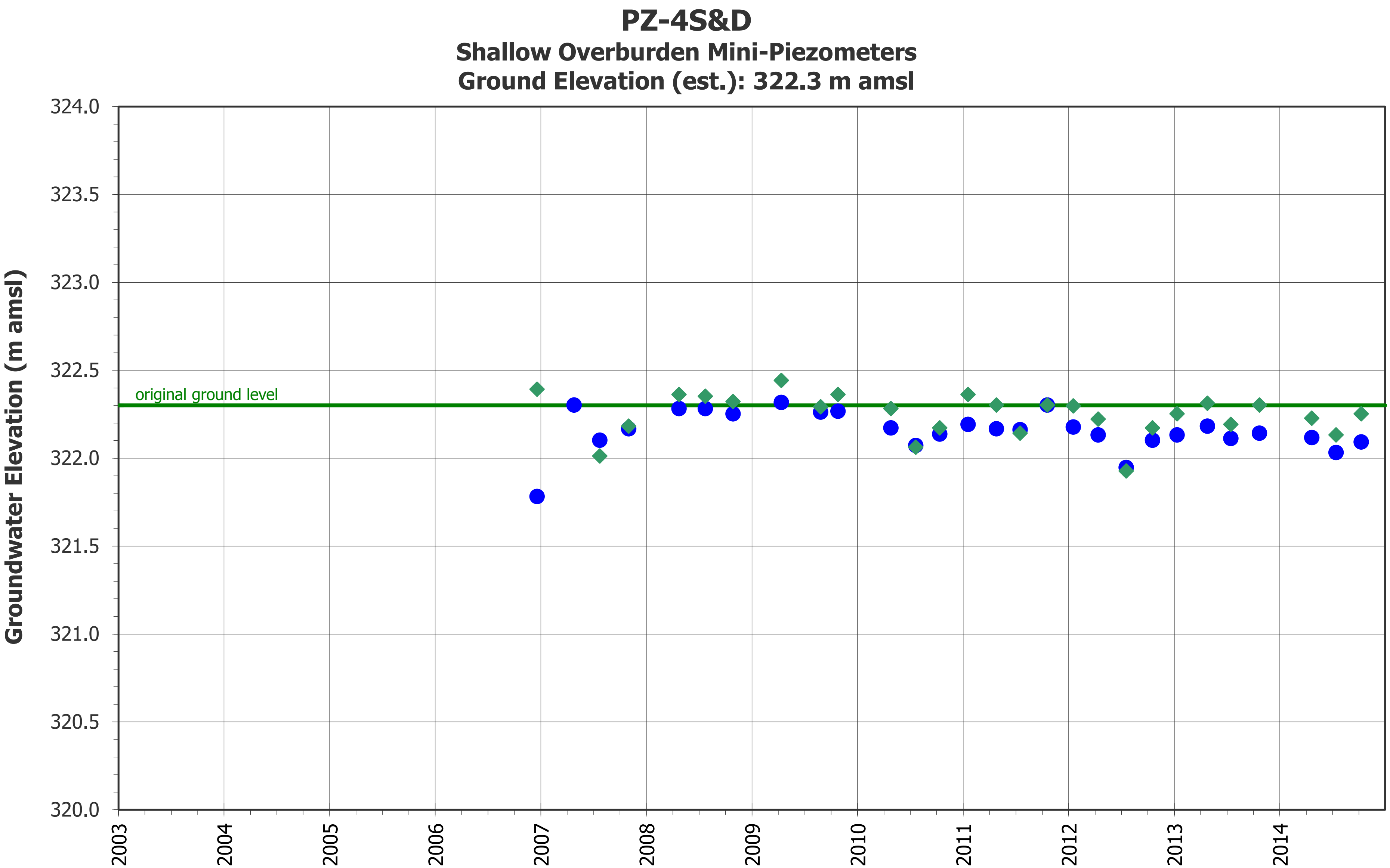
December 2014 **Phase 3- Core PSW** **Graph C 51**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 3 - Core PSW** **Graph C 52**



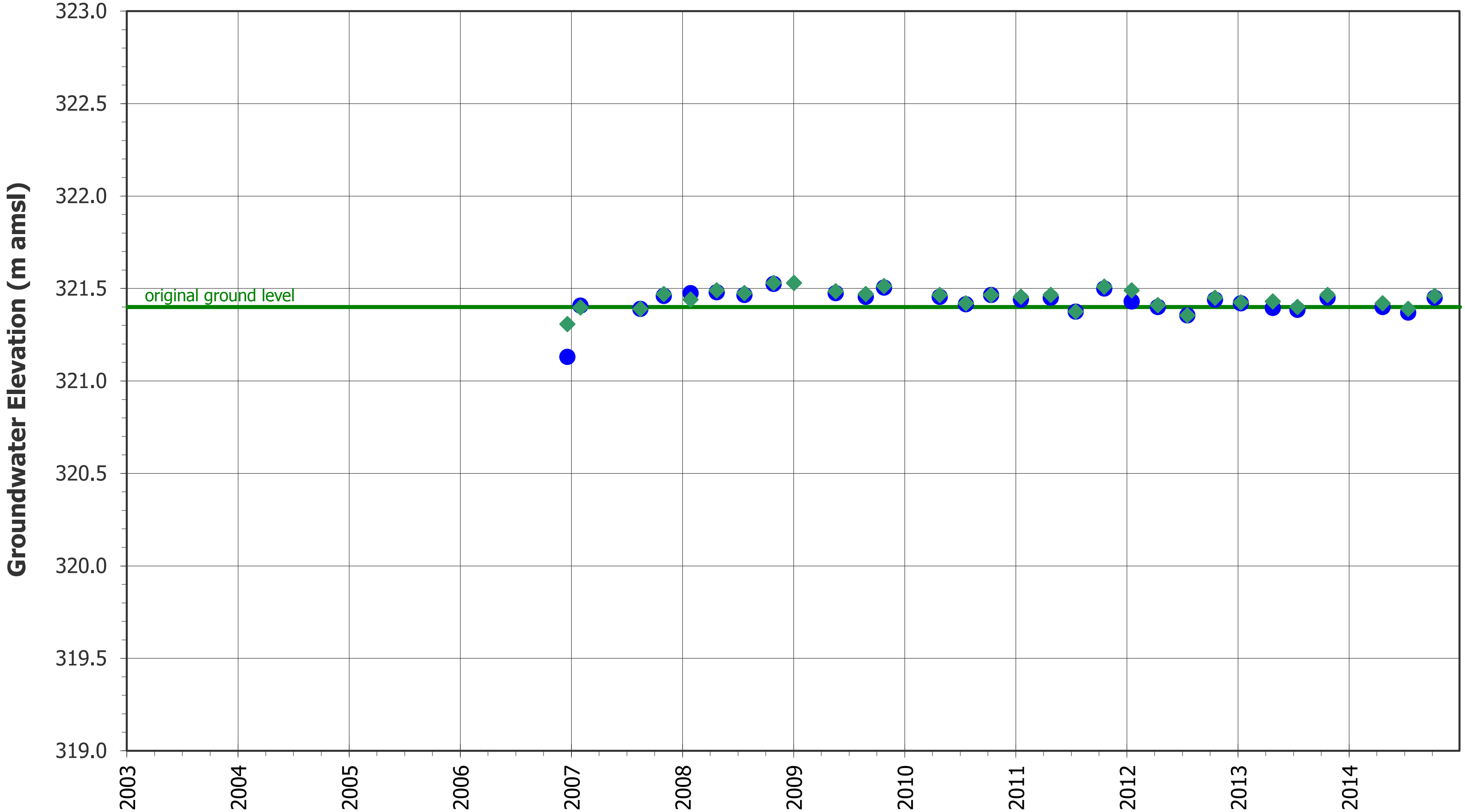
Banks Groundwater Engineering Limited

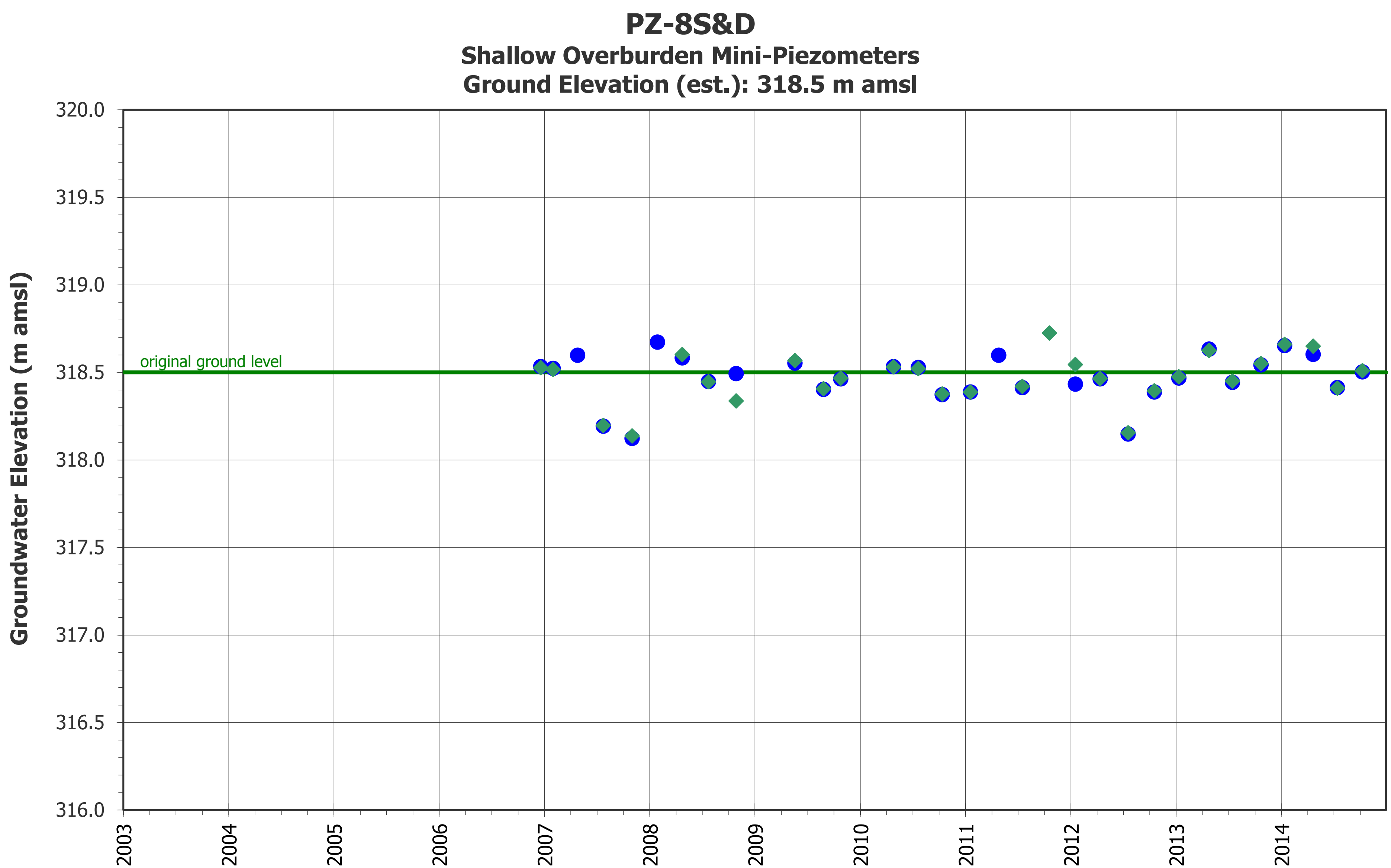
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014

Phase 1 - Core PSW Graph C 53

PZ-7S&D
Shallow Overburden Mini-Piezometers
Ground Elevation (est.): 321.4 m amsl

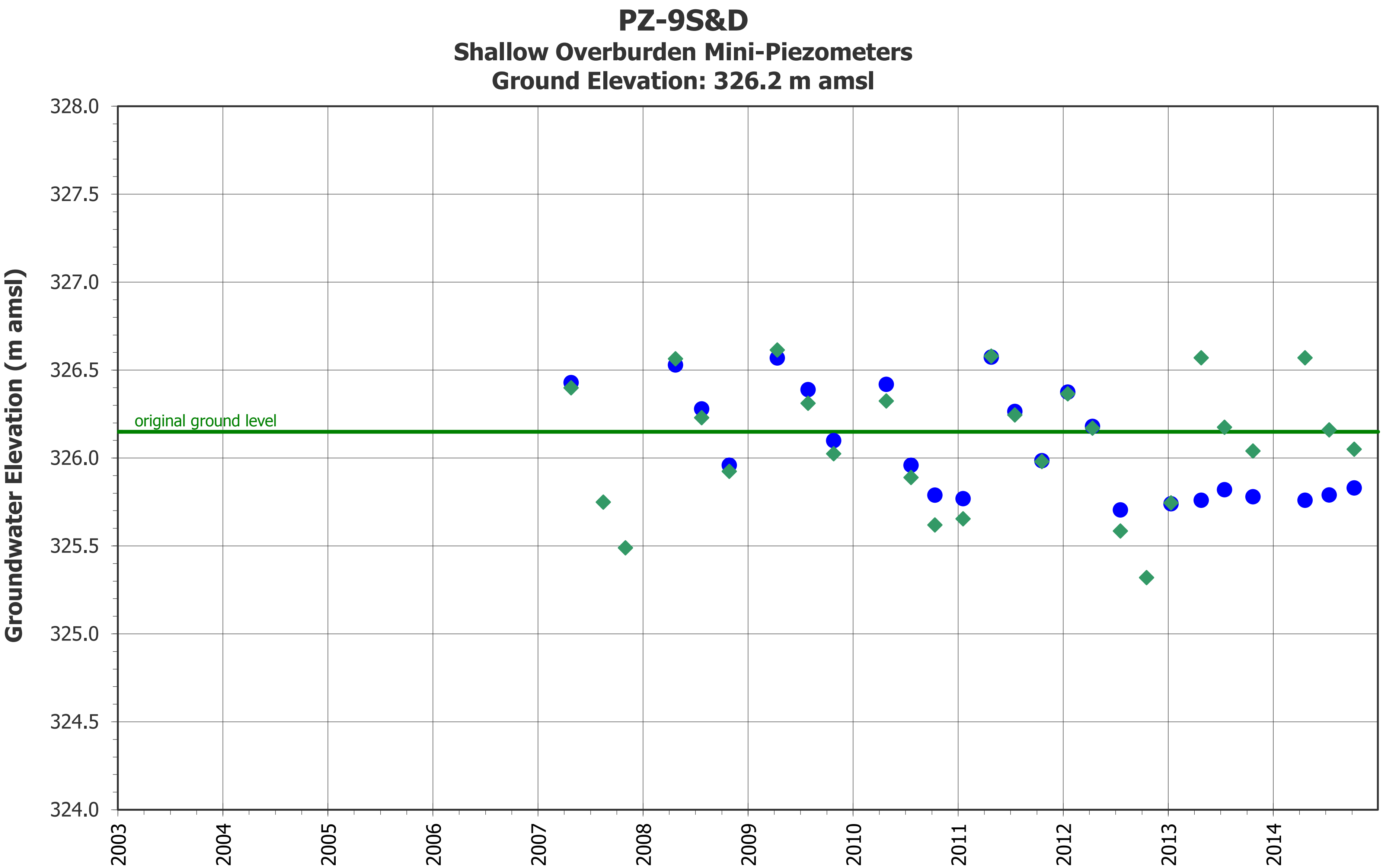




Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

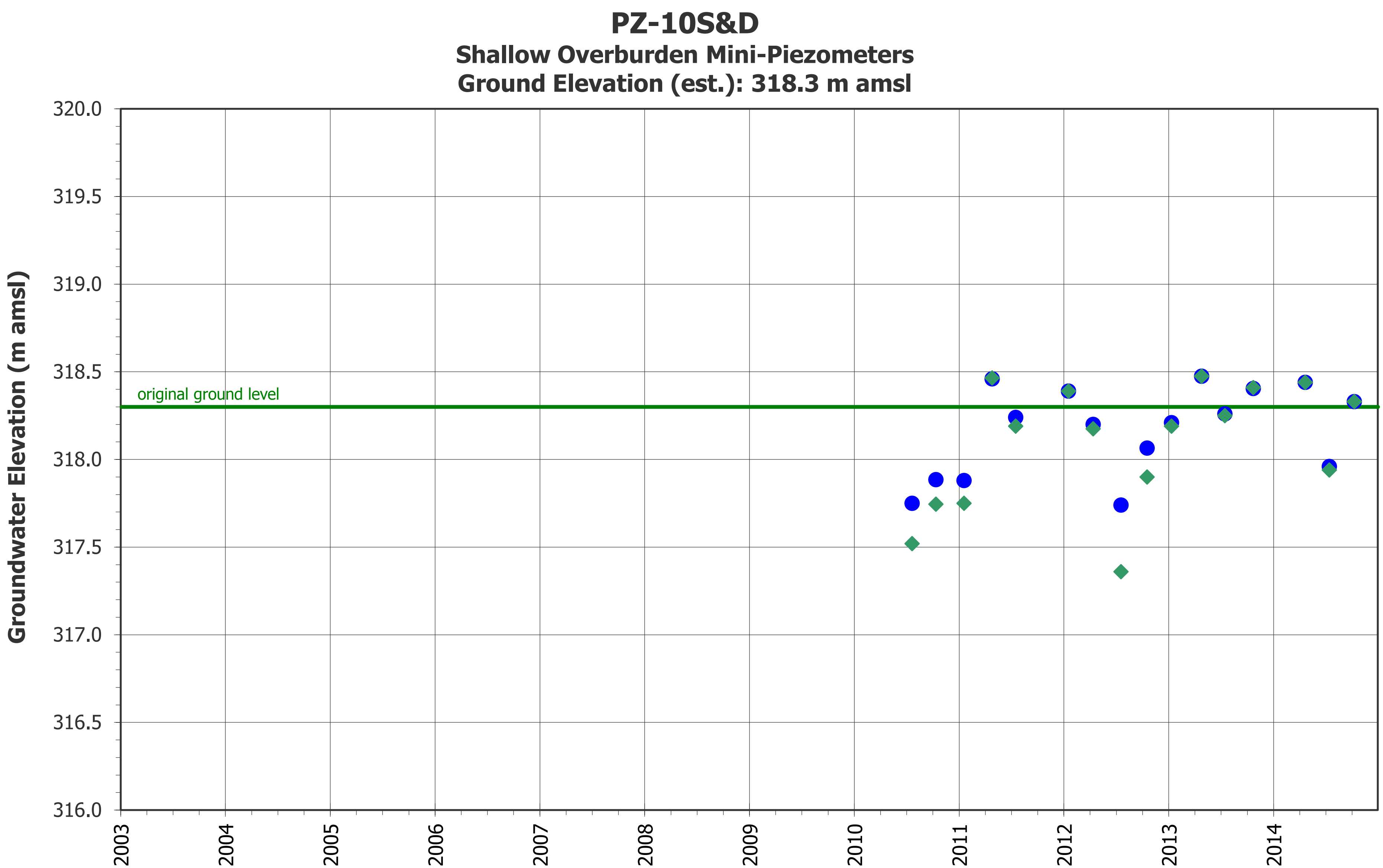
December 2014 **Phase 1 - Core PSW** **Graph C 55**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

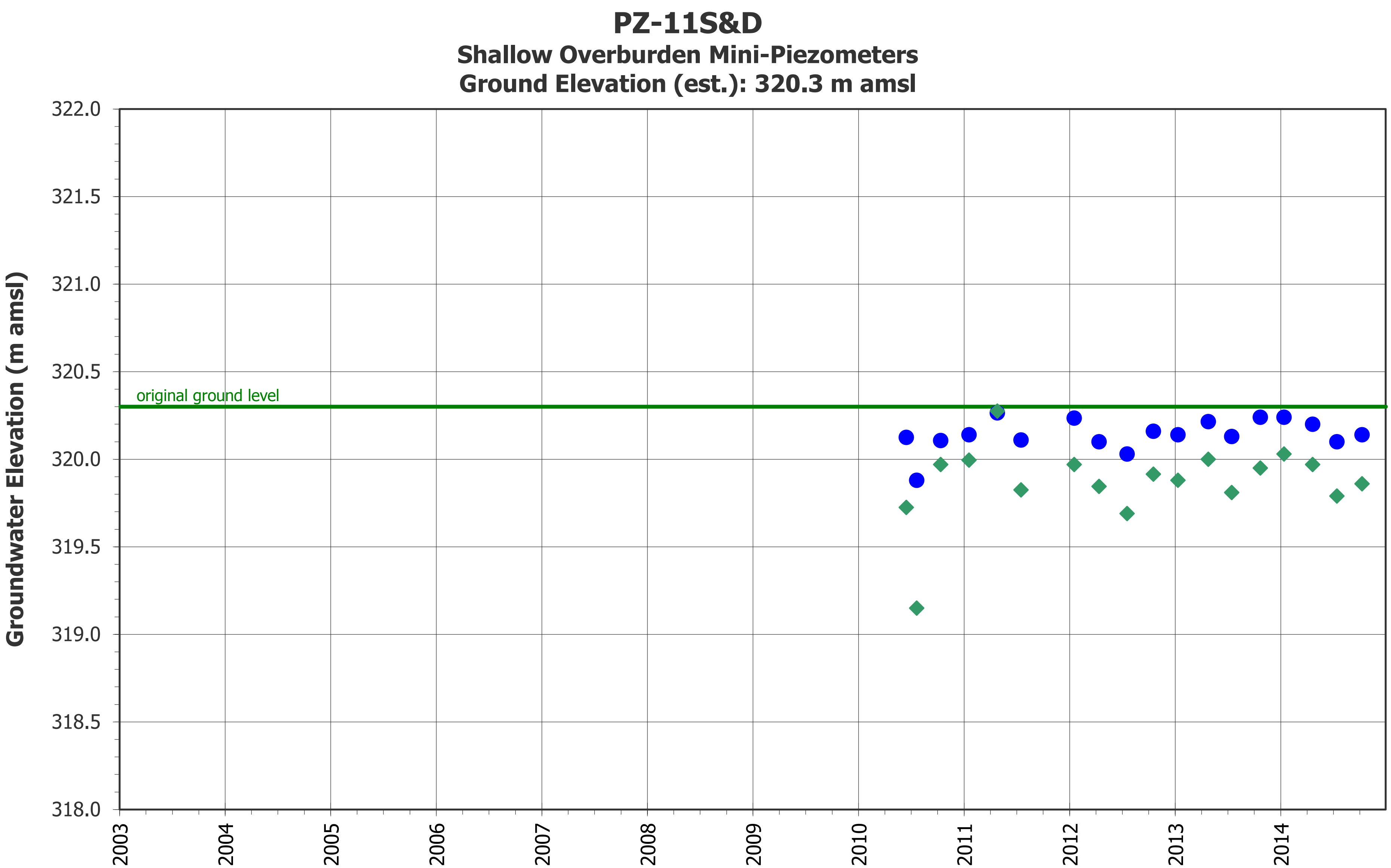
December 2014 **Phase 3 - Downey Rd. PSW** **Graph C 56**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

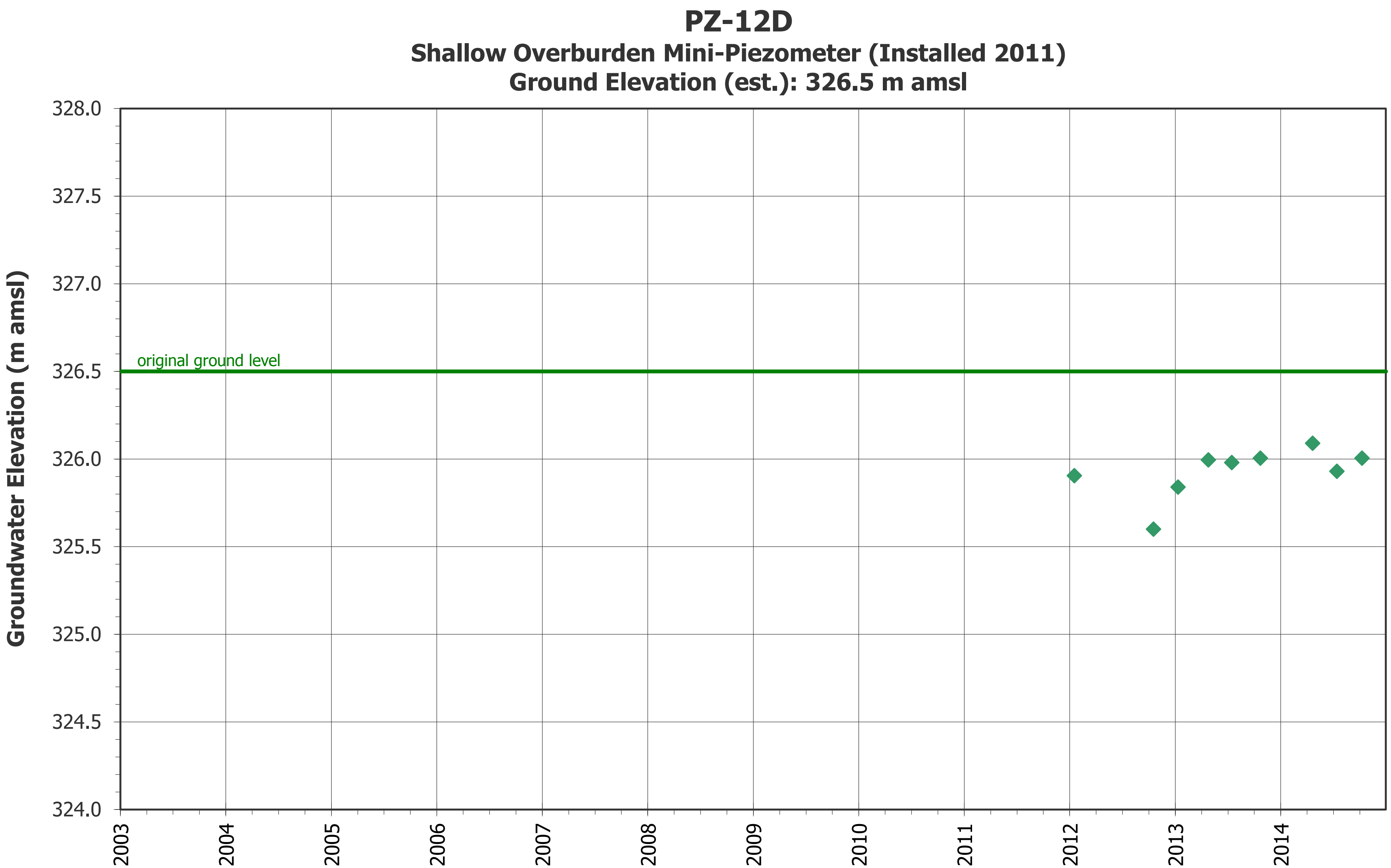
December 2014 **Phase 1 - Core PSW** **Graph C 57**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph C 58**



Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Core PSW** **Graph C 59**

Appendix D

Vertical Hydraulic Gradients
2003 – 2014

Hanlon Creek Business Park -Groundwater Monitoring Program

Vertical Hydraulic Gradient Data

Monitoring Well Number	Type	Groundwater Elevations (m amsl)															
		Sep-03	Apr-07	Jul-07	Nov-07	Jan-08	Apr-08	Jul-08	Oct-08	Jan-09	Apr-09	Jul-09	Oct-09	Jan-10	Apr-10	Jul-10	Oct-10
001	S	323.96	324.33	323.87	323.67	324.29	324.42	324.22	324.03	324.40	324.43	324.20	324.10	324.16	324.22	323.89	323.85
002	S	325.39	damaged	325.33	325.27	325.95	325.01	325.91	325.83								
003	S	325.61	326.57	325.89	325.48	326.17	326.58	326.22	325.92	326.56	326.64	326.30	326.01	326.10	326.35	325.91	325.64
004	S	325.72	327.03	326.19	325.52	326.22	327.53	326.49	326.03	326.87	327.29	326.54	326.08	326.10	326.67	326.14	325.70
005 (S)	S	329.78	n/a	moist/dry	dry	330.10	330.20	330.33	330.05	330.52	330.11	330.07			330.09		
005 (I)	I	326.92	n/a	327.88	327.16	327.29	328.62	328.13	327.70	327.82	328.82	328.38	327.85	327.50	327.89	327.63	
006	S	326.97	328.27	327.74	327.11	327.46	328.54	328.05	327.62	327.99	328.66	328.21	327.76	327.51	327.84	327.56	
101	S	317.58	318.01	317.54	317.35	318.09	318.49	317.79	317.77	318.65	318.52	317.62	317.88	317.92	318.07	317.72	317.66
102	S	318.91	319.74	318.72	318.30	319.74	319.89	320.18	319.15	320.13	320.13	319.17	319.34	319.98	319.72		
103	S	322.63	323.33	322.44	322.40	323.33	323.44	323.05	322.79	323.55	323.51	322.90	322.80	322.90	323.11	322.57	322.52
104	S	320.83	321.49	320.59	320.70	321.46	321.43	321.30	321.14	321.55	321.61	321.14	321.17	321.28	321.24	320.87	320.82
105	S	322.60	322.93	322.48	322.62	322.77	322.82	322.77	322.72	322.84	322.93	322.79	322.79	322.81	322.76	322.53	322.66
106	S	325.78	326.66	326.07	325.76	326.39	326.83	326.50	326.19	326.77	326.93	326.48	326.28	326.29	326.41	326.08	
107	S	326.31	n/a	326.71	326.29	326.78	327.52	327.15	326.75	327.25	327.76	327.14	326.85	326.78	326.96	326.61	326.56
109	S	326.29	327.56	326.88	326.29	326.71	327.91	327.10	326.74	327.31	327.87	327.21	326.83	326.74	327.18	326.76	326.42
110	I	326.53	327.90	327.30	326.63	326.89	328.20	327.53	327.14	327.43	328.23	327.70	327.25	327.04	327.47	327.15	
111	D	324.60	324.95	325.03	324.67	325.18	325.93	325.05	324.86	325.05		325.22	324.73	324.78	324.94	324.66	324.53
112	D	325.47	326.49	325.77	325.35	325.97	327.07	326.26	325.81	326.54	326.79	326.24	325.55	325.57	325.97	325.64	325.31
113	D	325.42	326.73	326.10	325.55	325.89	326.95	326.26	325.88	326.17	326.87	326.42	325.84	325.71	326.06	325.74	
114	D	325.82	327.04	326.65	326.04	326.29	327.43	326.87	326.45	326.68	327.43	327.07	326.49	326.28	326.64	326.29	
115	I	323.02	322.77	323.14	323.19	frozen	323.76	323.76	323.45		323.76	323.55	323.50	323.61	323.62	323.19	323.33
115A	S	322.44	323.05	321.97	322.34	322.81	322.82	323.10	322.74	322.92	323.09	322.73	322.91	322.95	322.94	322.40	322.72
116	I	314.86	315.71	314.63	314.41	315.35	316.00	314.63	314.84		315.95	314.26	315.05	315.17	315.32	314.80	314.73
116A	S	317.92	318.50	317.58	317.56	318.47	318.49	318.27	318.21	318.57	318.53	318.27	318.18	318.27	318.28	317.74	317.89
117	I	318.09	318.19	318.05	318.04	318.55	318.84	318.06	318.25	318.85	318.79	317.82	318.33	318.38	318.40	317.82	318.28
117A	S	319.97	320.45	319.83	319.93	320.13	320.25	320.04	320.10	320.37	320.36	320.00	320.09	320.13	320.10	319.32	320.26
118	I	323.18	323.43	323.33	323.34	323.66	323.75	323.49	323.43	323.69	323.74	323.54	323.48	323.52	323.50	323.44	323.46
118A	S	323.16	323.45	322.99	323.04	323.31	323.33	323.26	323.20	323.48	323.50	323.30	323.25	323.29	323.26	323.05	323.10
119	I	324.76	325.37	324.72	324.85	325.15	325.22	325.35	325.18	325.27	325.42	325.25	325.24	325.26	325.19	325.23	325.04
119A	S	324.77	325.19	324.73	324.87	325.17	325.24	325.35	325.20	325.29	325.42	325.27	325.26	325.27	325.20	325.26	325.06
121	I	325.72	326.38	326.35	325.81	326.15	326.71	326.50	326.29	326.53	326.74	326.57	325.26	326.26	326.49	326.22	326.03
121A	S	326.44	damaged	326.99	326.84	326.58	327.30	327.13	326.94	327.15	327.34	327.19	326.38	326.90	327.11	326.86	326.66
122	I	325.93	326.30	326.07	325.96	326.14	326.30	326.30	326.13	326.28	326.38	326.26	327.01	326.14	326.20	326.29	326.03
122A	S	325.81	326.10	325.93	325.84	325.98	326.12	326.12	325.99	326.11	326.17	326.08	326.19	325.98	326.03	326.12	325.90
123	VD	n/a	305.83	305.14	304.55	310.53	311.64	308.11	306.97		307.22		326.03	305.50	305.68	304.96	304.80

S=Shallow; I=Intermediate; D=Deep (Bedrock)

Hanlon Creek Business Park -Groundwater Monitoring Program

Vertical Hydraulic Gradient Data

Monitoring Well Number	MW for Gradient Calc.	Mid-Point of Screen Elevation (m)	Vertical Hydraulic Gradient I (-ve = up)																
			Sep-03	Apr-07	Jul-07	Nov-07	Jan-08	Apr-08	Jul-08	Oct-08	Jan-09	Apr-09	Jul-09	Oct-09	Jan-10	Apr-10	Jul-10	Oct-10	average I
001	118	319.75	0.20	0.23	0.14	0.08	0.16	0.17	0.18	0.15	0.18	0.18	0.17	0.16	0.16	0.18	0.11	0.10	0.16
002	119	324.16	0.12	n/a	0.11	0.08	0.15	-0.04	0.11	0.12									0.09
003	122	323.56	-0.09	0.08	-0.05	-0.14	0.01	0.08	-0.02	-0.06	0.08	0.08	0.01	-0.29	-0.01	0.04	-0.11	-0.11	-0.03
004	112	324.38	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.03	0.02	0.02	0.02
005 (S)	005(I)	331.23	0.47	n/a	n/a	n/a	0.46	0.26	0.36	0.39	n/a	0.21	0.28			0.36			0.35
005 (I)	114	325.13	0.05	n/a	0.05	0.05	0.04	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.05	0.05	0.06		0.05
006	121	326.45	0.14	0.22	0.16	0.15	0.15	0.21	0.18	0.15	0.17	0.22	0.19	0.29	0.14	0.16	0.15		0.18
101	116	316.70	0.32	0.27	0.34	0.34	0.32	0.29	0.37	0.34		0.30	0.39	0.33	0.32	0.32	0.34	0.34	0.33
102	117	316.91	0.22	0.41	0.18	0.07	0.31	0.28	0.56	0.24	0.34	0.35	0.36	0.27	0.42	0.35			0.31
103	117	320.75	0.59	0.67	0.57	0.57	0.63	0.60	0.65	0.59	0.62	0.62	0.66	0.59	0.59	0.62	0.62	0.55	0.61
104	118	318.84	-0.76	-0.63	-0.89	-0.86	-0.72	-0.76	-0.71	-0.75	-0.70	-0.69		-0.75	-0.73	-0.74	-0.84	-0.86	-0.76
105	111	320.52	-0.11	-0.11	-0.14	-0.11	-0.13	-0.17	-0.12	-0.12	-0.12		-0.13	-0.11	-0.11	-0.12	-0.12	-0.10	-0.12
106	119	323.60	0.22	0.27	0.29	0.19	0.26	0.34	0.24	0.21	0.32	0.32	0.26	0.22	0.22	0.26	0.18		0.25
107	119	324.49	0.28	n/a	0.35	0.26	0.29	0.41	0.32	0.28	0.35	0.42	0.34	0.29	0.27	0.32	0.25	0.27	0.31
109	113	323.50	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.04	0.04	0.03	0.04	0.04	0.04	0.04		0.03
110	113	323.79	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05		0.05
111	105	302.10	-0.11	-0.11	-0.14	-0.11	-0.13	-0.17	-0.12	-0.12	-0.12		-0.13	-0.11	-0.11	-0.12	-0.12	-0.10	-0.12
112	004	300.29	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.03	0.02	0.02	0.02
113	110	296.30	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05		0.05
114	005(I)	302.13	0.05	n/a	0.05	0.05	0.04	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.05	0.05	0.06		0.05
115	115A	315.07	-0.10	0.05	-0.20	-0.14	n/a	-0.16	-0.11	-0.12		-0.11	-0.14	-0.10	-0.11	-0.11	-0.13	-0.10	-0.11
115A	115	321.00	-0.10	0.05	-0.20	-0.14	n/a	-0.16	-0.11	-0.12		-0.11	-0.14	-0.10	-0.11	-0.11	-0.13	-0.10	-0.11
116	116A	308.15	0.38	0.35	0.37	0.39	0.39	0.31	0.45	0.42		0.32	0.50	0.39	0.39	0.37	0.37	0.39	0.39
116A	116	316.17	0.38	0.35	0.37	0.39	0.39	0.31	0.45	0.42		0.32	0.50	0.39	0.39	0.37	0.37	0.39	0.39
117	117A	313.11	0.33	0.40	0.32	0.34	0.28	0.25	0.35	0.33	0.27	0.28	0.39	0.31	0.31	0.30	0.27	0.35	0.32
117A	117	318.75	0.33	0.40	0.32	0.34	0.28	0.25	0.35	0.33	0.27	0.28	0.39	0.31	0.31	0.30	0.27	0.35	0.32
118	118A	315.77	-0.003	0.004	-0.07	-0.06	-0.07	-0.08	-0.04	-0.04	-0.04	-0.05	-0.05	-0.04	-0.04	-0.05	-0.07	-0.07	-0.05
118A	118	320.92	-0.003	0.004	-0.07	-0.06	-0.07	-0.08	-0.04	-0.04	-0.04	-0.05	-0.05	-0.04	-0.04	-0.05	-0.07	-0.07	-0.05
119	119A	318.88	0.00	-0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00
119A	119	322.53	0.00	-0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00
121	121A	317.79	0.11	n/a	0.09	0.15	0.06	0.09	0.09	0.09	0.09	0.09	0.09	0.17	0.09	0.09	0.09	0.09	0.10
121A	121	324.59	0.11	n/a	0.09	0.15	0.06	0.09	0.09	0.09	0.09	0.09	0.09	0.17	0.09	0.09	0.09	0.09	0.10
122	122A	320.09	-0.03	-0.06	-0.04	-0.04	-0.05	-0.05	-0.05	-0.04	-0.05	-0.06	-0.05	-0.24	-0.05	-0.05	-0.05	-0.04	-0.06
122A	122	323.51	-0.03	-0.06	-0.04	-0.04	-0.05	-0.05	-0.05	-0.04	-0.05	-0.06	-0.05	-0.24	-0.05	-0.05	-0.05	-0.04	-0.06
123	111	272.78	n/a	0.65	0.68	0.69	0.50	0.49	0.58	0.61				-0.04	0.66	0.66	0.67	0.67	0.57

S=Shallow; I=Intermediate; D=Deep (Bedrock)

Hanlon Creek Business Park -Groundwater Monitoring Program

Vertical Hydraulic Gradient Data

Monitoring Well Number	Type	Groundwater Elevations (m amsl)															
		Jan-11	Apr-11	Jul-11	Oct-11	Jan-12	Apr-12	Jul-12	Oct-12	Jan-13	Apr-13	Jul-13	Oct-13	Jan-14	Apr-14	Jul-14	Oct-14
003	S	325.68	326.61	326.24	325.97	326.35	326.15	325.57	325.30	325.73	326.56	326.15	326.02	326.40	326.56	326.14	326.03
004	S	325.67	326.80	326.78	325.88	326.44	326.40	325.76	325.32	325.69	327.16	326.50	325.96	326.26	327.13	326.49	326.11
103	S	322.50	323.27	322.41	322.62	322.91	322.59	322.10	322.42	322.67	323.21	322.77	322.89	322.90	323.19	322.50	322.87
104	S	320.92	321.42	321.10	321.28	321.30	321.06	320.62	320.87	321.31	321.50	321.18	321.33	321.47	321.39	320.97	321.25
105	S	322.64	322.90	322.62	323.04	322.78	322.69	322.33	322.67	322.75	322.85	322.62	322.82	322.86	322.81	322.58	322.77
107	S	326.14	327.00	326.67	326.22	326.42	326.32	326.06	325.98	326.07	326.66	326.59	326.45	326.43	326.68	326.54	326.49
111	D	324.47	325.15	325.01	324.70	324.90	324.90	324.42	324.40	324.66	325.39	324.92	325.02	0.00	325.27	325.03	324.95
112	D	325.29	326.35	326.18	325.56	326.11	325.96	325.23	325.12	325.48	326.77	326.18	325.76	326.07	326.79	326.13	325.88
115	I	323.48	323.75	323.28	323.57	323.61	323.58	322.83	323.21	323.46	323.76	323.51	323.62	323.71	323.76	323.47	323.65
115A	S	322.80	323.07	322.28	323.10	322.95	322.92	321.94	322.65	322.95	322.99	322.62	322.97	323.03	323.00	322.55	322.93
116	I	314.77	315.79	315.24	315.23	315.56	315.10	314.55	314.77	315.14	315.87	315.48	315.95	315.53	315.96	315.23	315.57
116A	S	317.92	318.39	318.10	318.47	318.34	318.14	317.51	317.97	318.22	318.39	318.15	318.30	318.43	318.36	317.96	318.22
117	I	318.29	318.81	318.31	318.59	318.54	318.27	317.99	318.27	318.39	318.67	318.43	318.70	318.63	318.69	318.29	318.53
117A	S	320.29	320.58	320.08	320.70	320.23	320.11	319.97	320.18	320.18	320.25	320.08	320.22	320.29	320.22	320.06	320.14
118	I	323.41	323.73	323.21	323.47	323.56	323.43	323.02	323.40	323.46	323.67	323.52	323.60	323.64	323.64	323.28	323.44
118A	S	323.04	323.34	322.81	323.21	323.19	323.05	322.69	323.04	323.11	323.25	323.09	323.21	323.24	323.21	323.00	323.18
119	I	325.30	325.68	323.76	325.12	324.99	324.91	324.84	324.88	324.88	324.97	324.90	324.96	325.08	324.98	324.87	324.92
119A	S	325.30	325.68	323.77	325.15	325.02	324.94	324.86	324.90	324.91	324.99	324.92	324.99	325.10	325.01	324.89	324.94
121	I	325.81	326.49	326.61	326.24	326.22	326.24	325.82	325.57	325.72	326.49	326.41	326.20	326.26	326.52	326.41	326.26
121A	S	326.44	327.12	327.20	326.87	326.87	326.89	326.46	326.20	326.36	327.11	327.04	326.84	326.89	327.14	327.05	326.91
122	I	325.99	326.31	326.00	326.17	326.17	326.13	325.91	325.83	326.01	326.29	326.15	326.15	326.25	326.29	326.15	326.14
122A	S	325.86	326.11	326.04	326.02	326.01	325.97	325.79	325.72	325.88	326.10	325.98	325.99	326.06	326.08	325.98	325.98
123	D+	304.76	306.54	306.81	308.29	308.32	312.91	305.61	307.36	307.84	308.63	306.68	306.82	306.98	307.82	307.03	307.00
124	S					320.29	319.83	319.20	319.28	320.20	319.91	319.96	320.34	320.43	320.39	319.56	320.23
125	S					314.83	314.40	314.03	314.22	314.44	315.18	314.69	315.08	314.76	315.28	314.53	314.72
126	S					317.35	316.82	315.62	316.02	316.85	317.64	317.89	318.10	317.98	318.16	317.51	318.04
127	S					318.55	318.39	318.20	318.40	318.49	318.66	318.50	318.61	318.64	318.68	318.46	318.58
128	S					320.29	320.20	319.94	320.10	320.21	320.43	320.32	320.36	320.40	320.40	320.23	320.35
129	S					325.07	324.87	324.62	324.91	324.97	325.24	325.04	325.16	325.23	325.25	324.96	325.11
130A	S					322.65		322.14	322.56	322.58	322.75	322.53	322.67	322.73	322.69	322.45	322.65
131	S					325.39	325.33	325.53	325.68	325.74	326.06	325.93	325.97	326.10	326.06	325.91	325.92
132	S					327.73	327.68	327.38	327.16	327.16	327.93	328.02	327.72	327.62	327.97	328.01	327.89
133	I					328.03	328.11	327.73	327.40	327.33	328.22	328.50	328.12	327.96	328.32	328.54	328.28
134	I					327.06	327.16	326.63	326.27	326.43	327.57	327.31	326.91	326.96	327.61	327.35	327.03
135	I					327.20	327.24	326.85	326.55	326.60	327.49	327.53	327.17	327.11	327.54	327.54	327.30

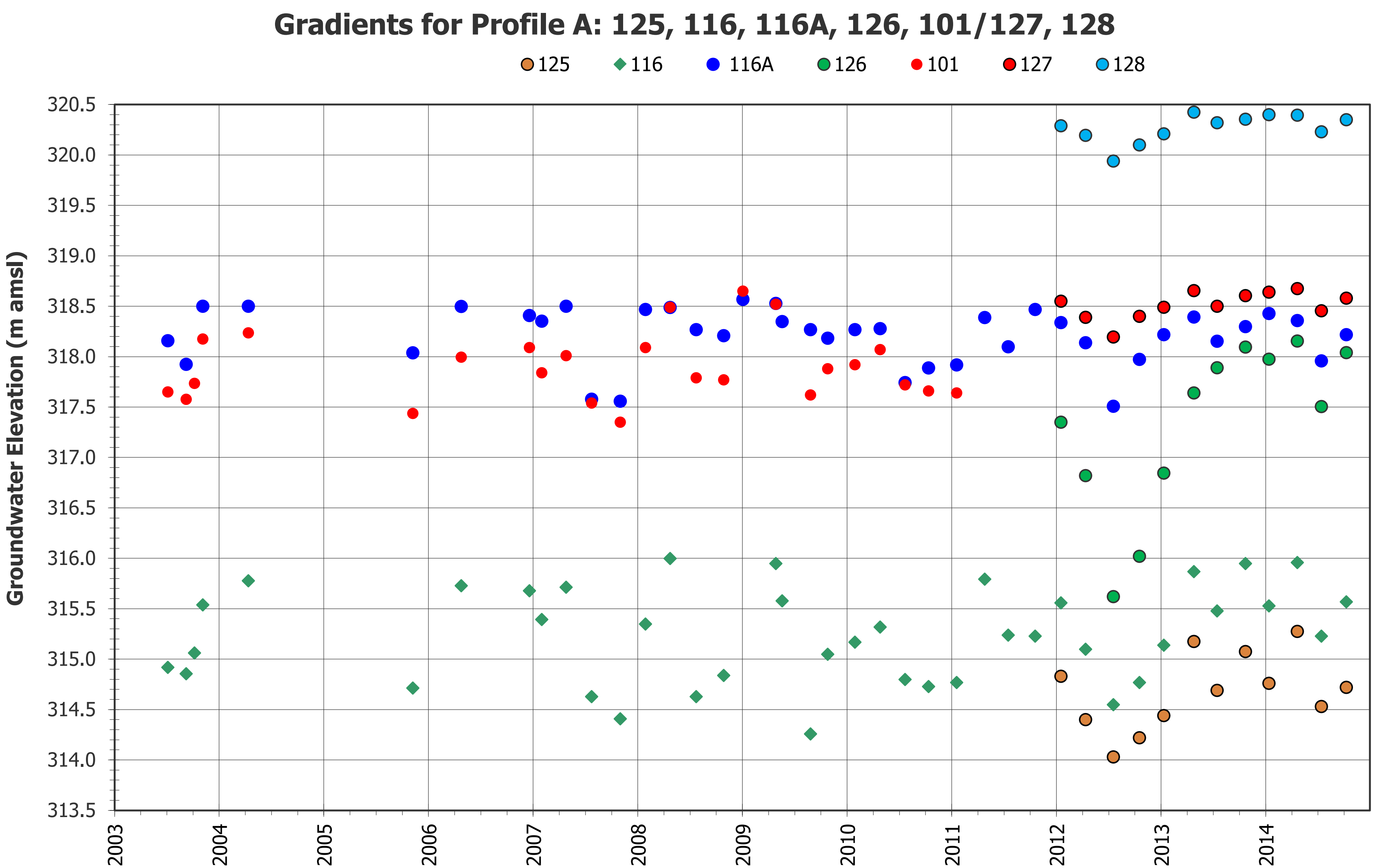
S=Shallow; I=Intermediate; D=Deep (Bedrock)

Hanlon Creek Business Park -Groundwater Monitoring Program

Vertical Hydraulic Gradient Data

Monitoring Well Number	MW for Gradient Calc.	Mid-Point of Screen Elevation (m)	Vertical Hydraulic Gradient I (-ve = up)																
			Jan-11	Apr-11	Jul-11	Oct-11	Jan-12	Apr-12	Jul-12	Oct-12	Jan-13	Apr-13	Jul-13	Oct-13	Jan-14	Apr-14	Jul-14	Oct-14	average I
003	122	323.56	-0.09	0.09	0.07	-0.06	0.05	0.01	-0.10	-0.15	-0.08	0.08	0.00	-0.04	0.04	0.08	-0.00	-0.03	-0.01
004	112	324.38	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
103	117	320.75	0.55	0.58	0.54	0.53	0.57	0.57	0.54	0.54	0.56	0.59	0.57	0.55	0.56	0.59	0.55	0.57	0.56
104	118	318.84	-0.81	-0.75	-0.69	-0.71	-0.74	-0.77	-0.78	-0.82	-0.70	-0.71	-0.76	-0.74	-0.71	-0.73	-0.75	-0.71	-0.74
105	111	320.52	-0.10	-0.12	-0.13	-0.09	-0.12	-0.12	-0.11	-0.09	-0.10	-0.14	-0.12	-0.12	17.53	-0.13	-0.13	-0.12	0.99
107	119	324.49	0.15	0.24	0.52	0.20	0.25	0.25	0.22	0.20	0.21	0.30	0.30	0.26	0.24	0.30	0.30	0.28	0.26
111	105	302.10	-0.10	-0.12	-0.13	-0.09	-0.12	-0.12	-0.11	-0.09	-0.10	-0.14	-0.12	-0.12	17.53	-0.13	-0.13	-0.12	0.99
112	004	300.29	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
115	115A	315.07	-0.11	-0.11	-0.17	-0.08	-0.11	-0.11	-0.15	-0.09	-0.09	-0.13	-0.15	-0.11	-0.11	-0.13	-0.16	-0.12	-0.12
115A	115	321.00	-0.11	-0.11	-0.17	-0.08	-0.11	-0.11	-0.15	-0.09	-0.09	-0.13	-0.15	-0.11	-0.11	-0.13	-0.16	-0.12	-0.12
116	116A	308.15	0.39	0.32	0.36	0.40	0.35	0.38	0.37	0.40	0.38	0.31	0.33	0.29	0.36	0.30	0.34	0.33	0.35
116A	116	316.17	0.39	0.32	0.36	0.40	0.35	0.38	0.37	0.40	0.38	0.31	0.33	0.29	0.36	0.30	0.34	0.33	0.35
117	117A	313.11	0.35	0.31	0.31	0.37	0.30	0.33	0.35	0.34	0.32	0.28	0.29	0.27	0.29	0.27	0.31	0.29	0.31
117A	117	318.75	0.35	0.31	0.31	0.37	0.30	0.33	0.35	0.34	0.32	0.28	0.29	0.27	0.29	0.27	0.31	0.29	0.31
118	118A	315.77	-0.07	-0.08	-0.08	-0.05	-0.07	-0.07	-0.07	-0.07	-0.07	-0.08	-0.08	-0.07	-0.08	-0.08	-0.05	-0.05	-0.07
118A	118	320.92	-0.07	-0.08	-0.08	-0.05	-0.07	-0.07	-0.07	-0.07	-0.07	-0.08	-0.08	-0.07	-0.08	-0.08	-0.05	-0.05	-0.07
119	119A	318.88	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.01
119A	119	322.53	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.01
121	121A	317.79	0.09	0.09	0.09	0.09	0.09	0.10	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
121A	121	324.59	0.09	0.09	0.09	0.09	0.09	0.10	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
122	122A	320.09	-0.04	-0.06	0.01	-0.05	-0.05	-0.05	-0.04	-0.03	-0.04	-0.06	-0.05	-0.05	-0.06	-0.06	-0.05	-0.05	-0.04
122A	122	323.51	-0.04	-0.06	0.01	-0.05	-0.05	-0.05	-0.04	-0.03	-0.04	-0.06	-0.05	-0.05	-0.06	-0.06	-0.05	-0.05	-0.04
123	111	272.78	0.67	0.63	0.62	0.56	0.57	0.41	0.64	0.58	0.57	0.57	0.62	0.62	-10.47	0.60	0.61	0.61	-0.10
124	117	315.47					0.74	0.66	0.51	0.43	0.77	0.53	0.65	0.69	0.76	0.72	0.54	0.72	0.64
125	116	313.57					-0.13	-0.13	-0.10	-0.10	-0.13	-0.13	-0.15	-0.16	-0.14	-0.13	-0.13	-0.16	-0.13
126	116	314.51					0.28	0.27	0.17	0.20	0.27	0.28	0.38	0.34	0.38	0.35	0.36	0.39	0.30
127	116	316.07					0.38	0.42	0.46	0.46	0.42	0.35	0.38	0.34	0.39	0.34	0.41	0.38	0.39
128	116	316.10					0.60	0.64	0.68	0.67	0.64	0.57	0.61	0.55	0.61	0.56	0.63	0.60	0.61
129	119	320.04					0.06	-0.04	-0.19	0.03	0.08	0.23	0.12	0.17	0.13	0.23	0.08	0.16	0.09
130A	118	322.19					-0.14		-0.14	-0.13	-0.14	-0.14	-0.15	-0.14	-0.14	-0.15	-0.13	-0.12	-0.14
131	119	322.90					0.10	0.10	0.17	0.20	0.21	0.27	0.26	0.25	0.25	0.27	0.26	0.25	0.22
132	121	326.12					0.18	0.17	0.19	0.19	0.17	0.17	0.19	0.18	0.16	0.17	0.19	0.20	0.18
133	135	326.04					0.26	0.27	0.28	0.27	0.23	0.23	0.31	0.30	0.27	0.24	0.31	0.31	0.27
134	121	325.13					0.11	0.13	0.11	0.10	0.10	0.15	0.12	0.10	0.10	0.15	0.13	0.10	0.12
135	121	322.85					0.19	0.20	0.20	0.19	0.17	0.20	0.22	0.19	0.17	0.20	0.22	0.21	0.20

S=Shallow; I=Intermediate; D=Deep (Bedrock)



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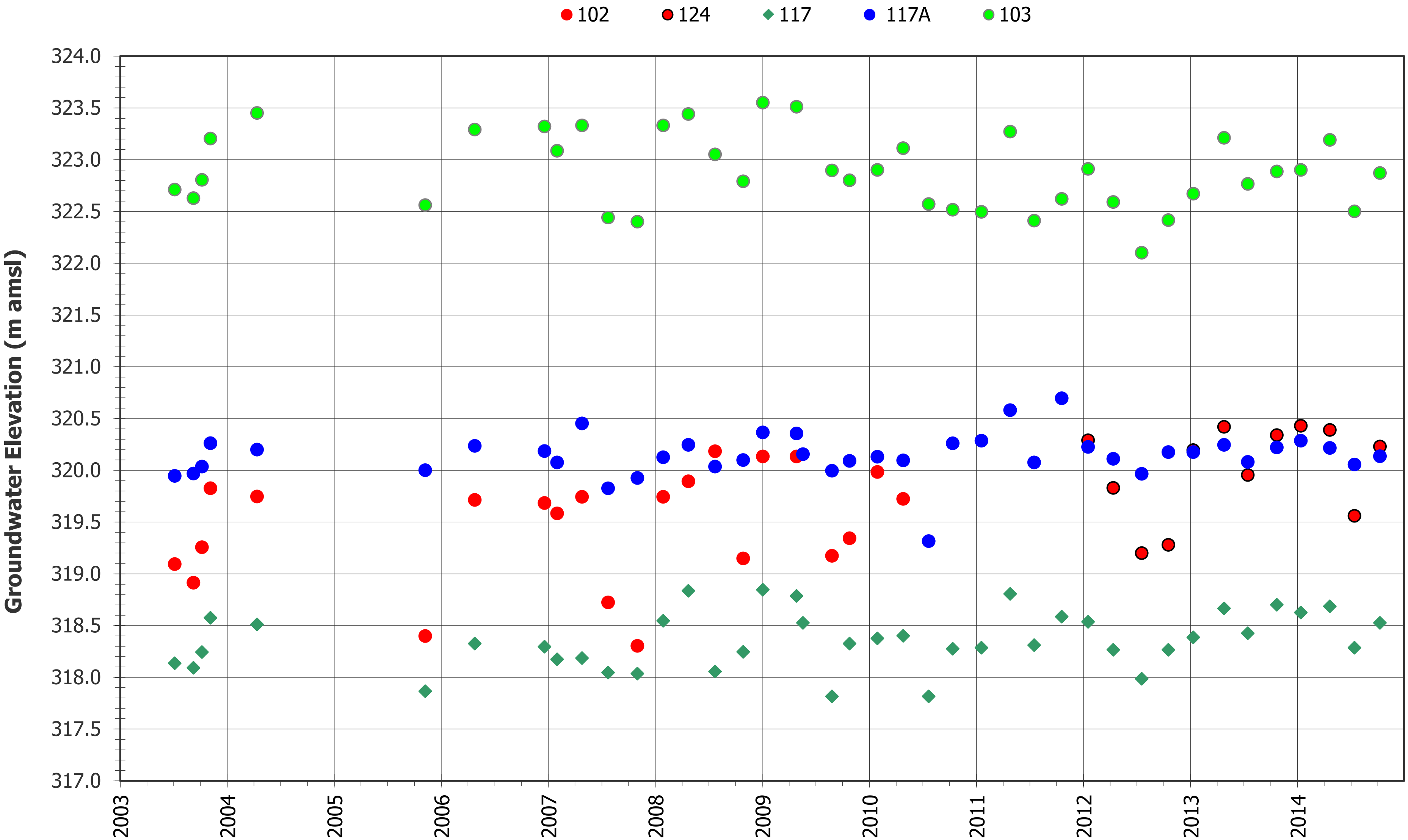
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph D 1**

Gradients for Profile B: 102/124, 117, 117A, 103



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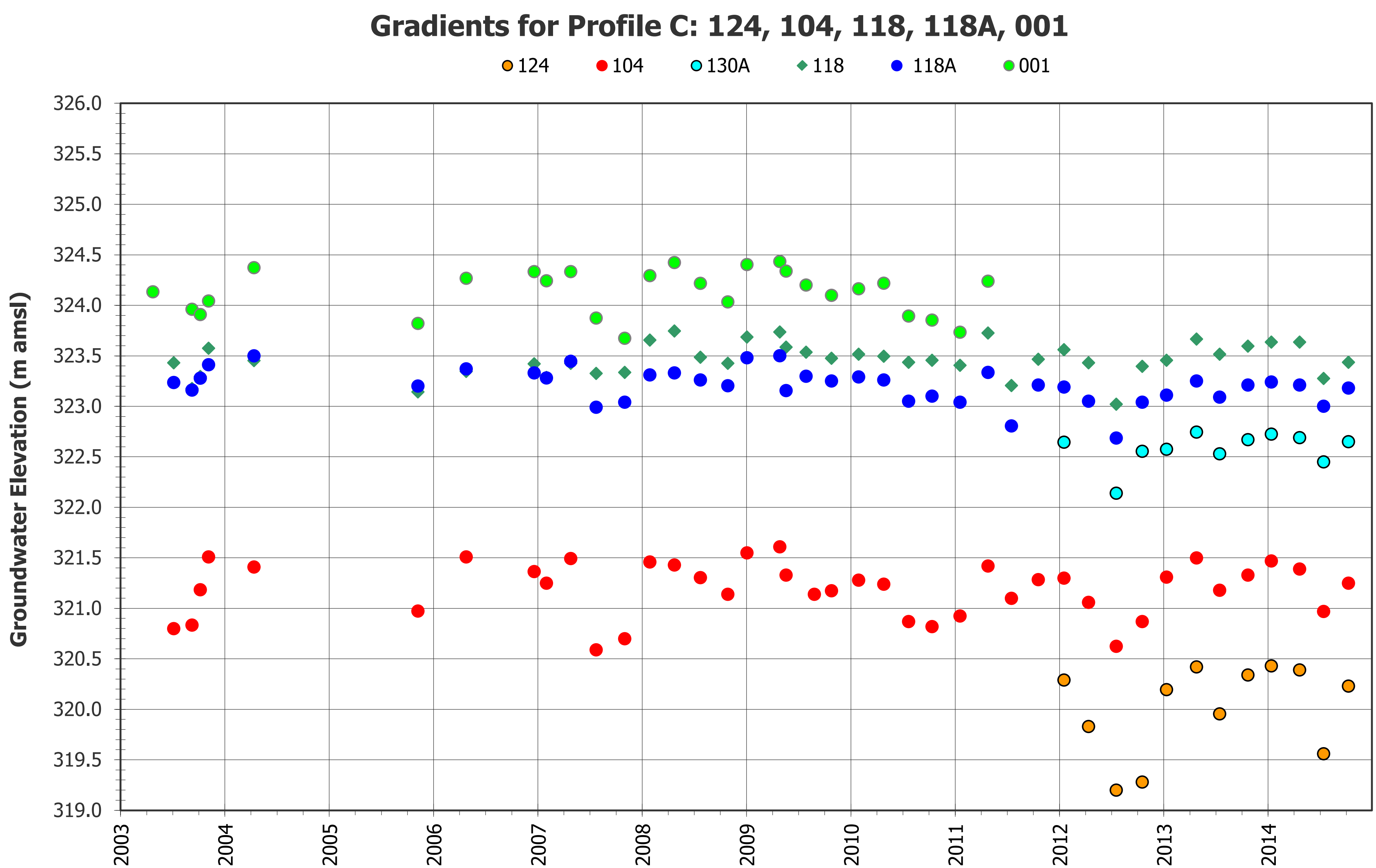
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW/Perimeter** **Graph D 2**



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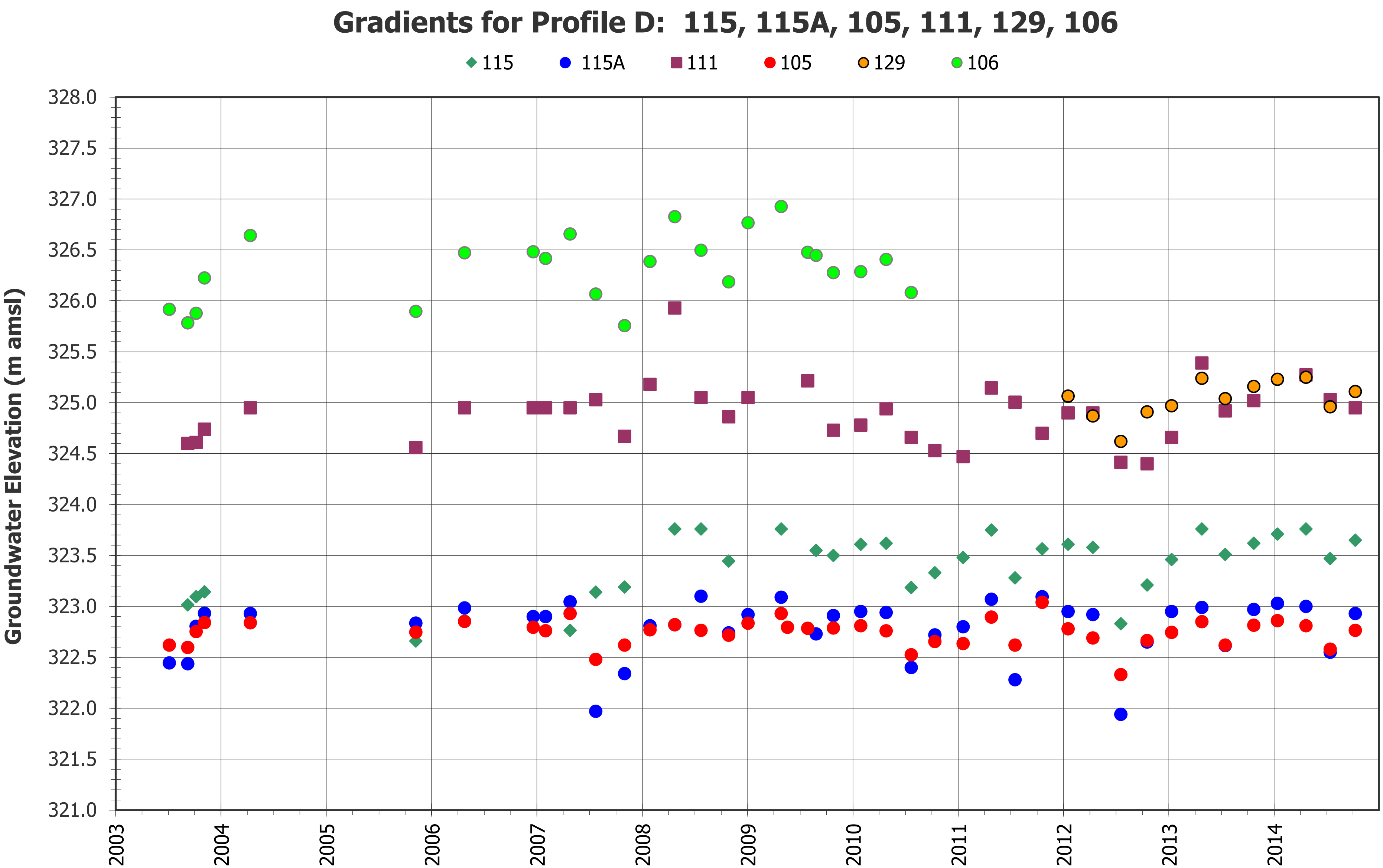
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph D 3**



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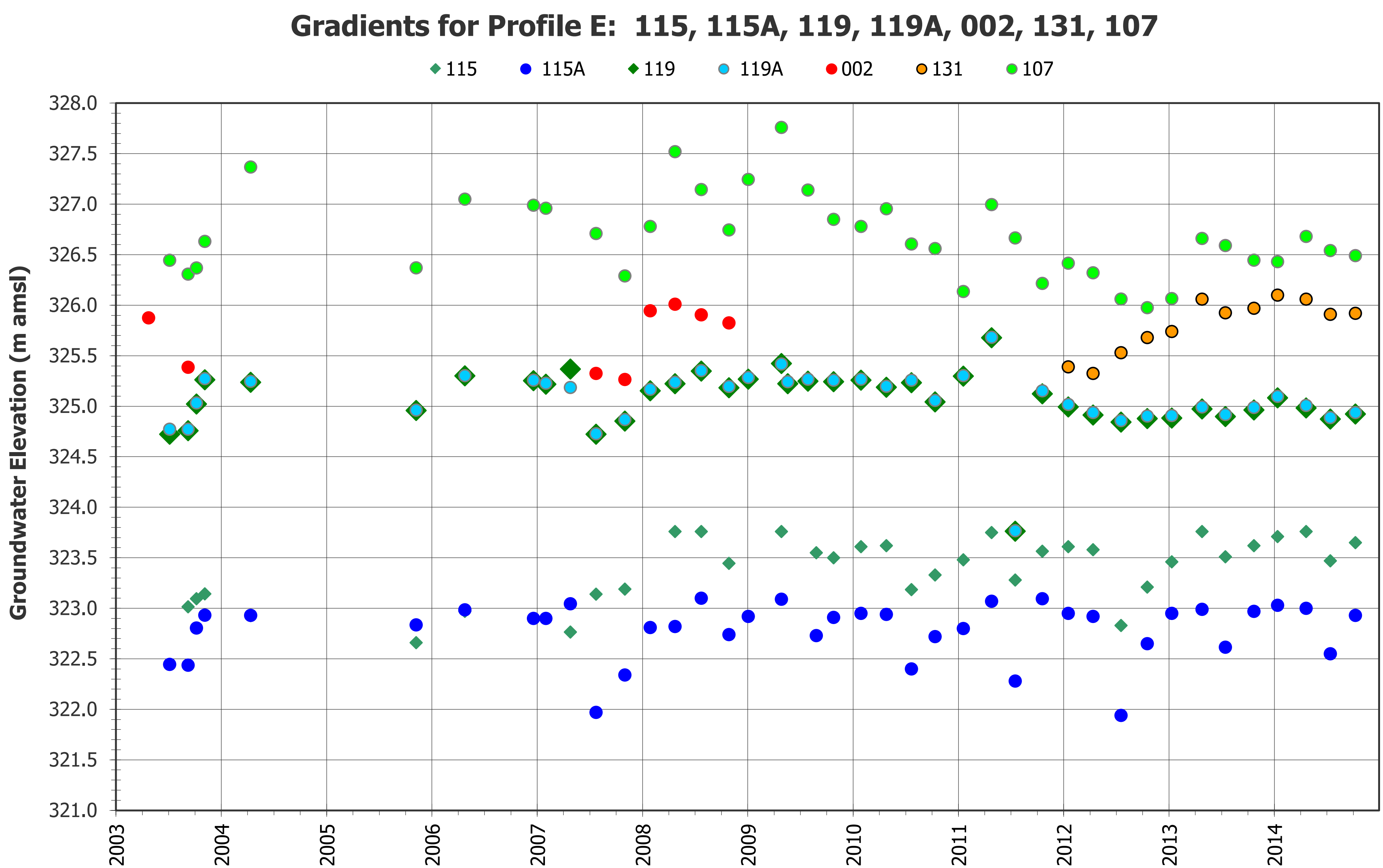
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phases 1/2 - Core PSW** **Graph D 4**



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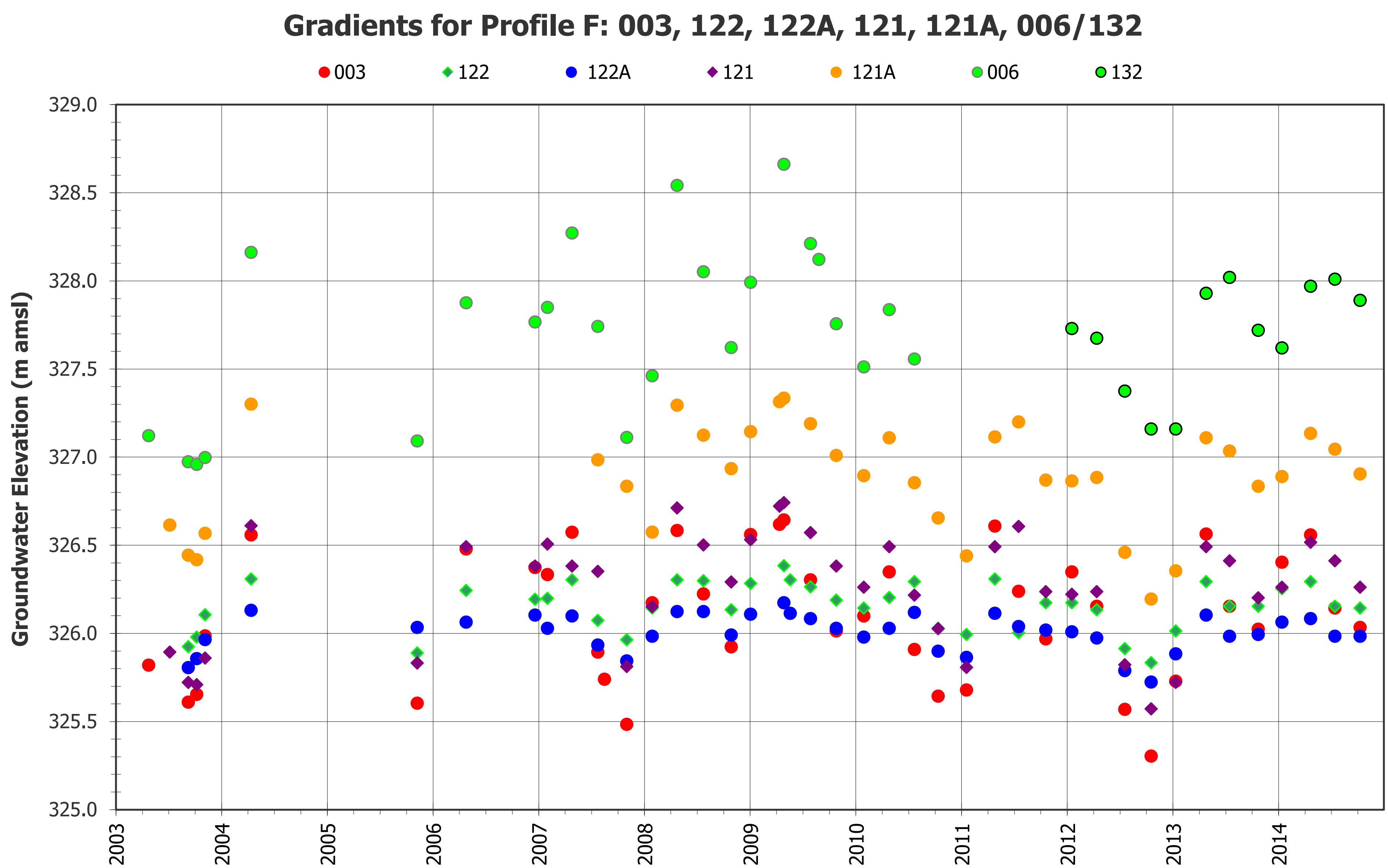
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phases 1/2 - Core PSW/Perimeter** **Graph D 5**



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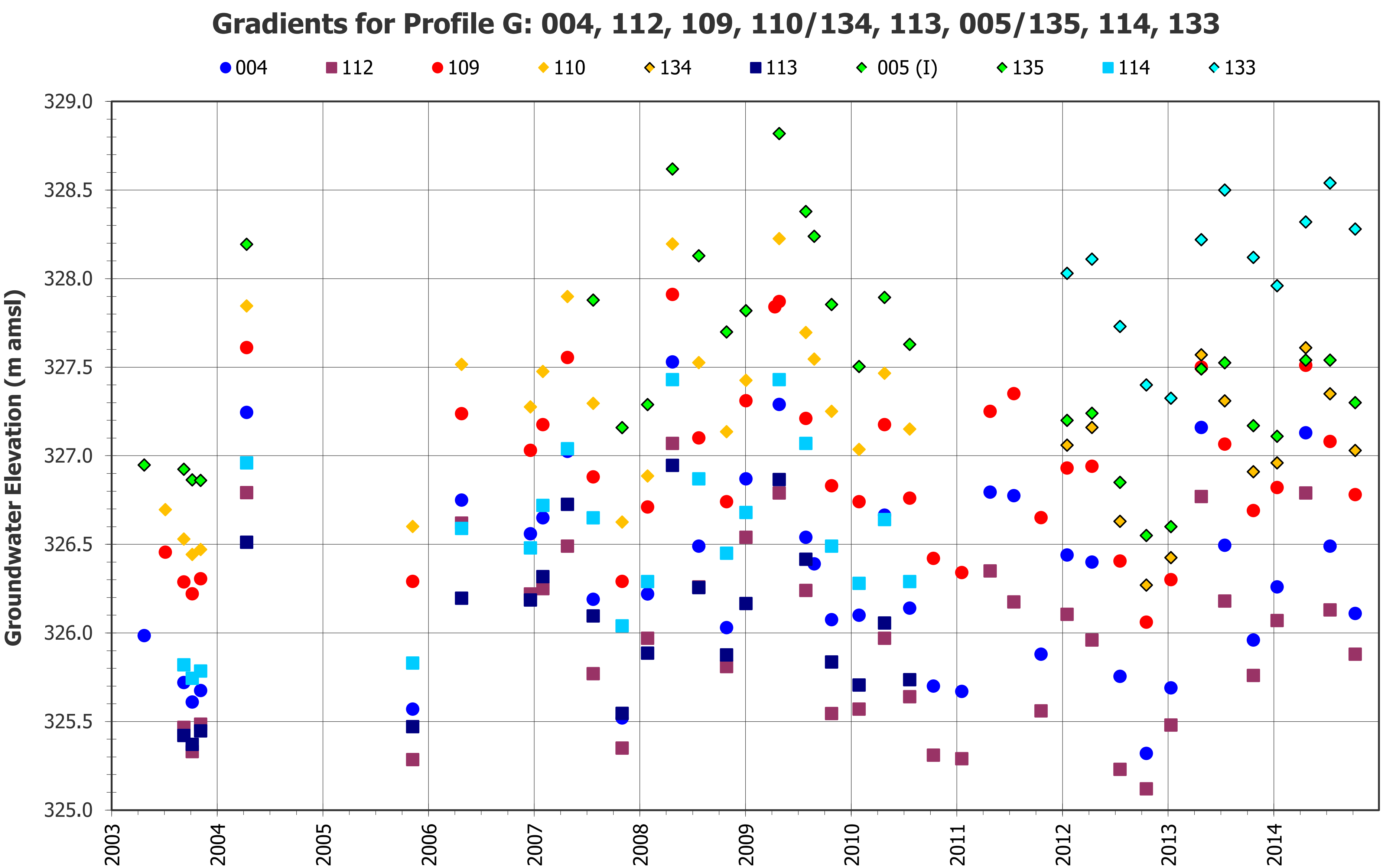
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phases 2/3 - Core PSW/Perimeter** **Graph D 6**

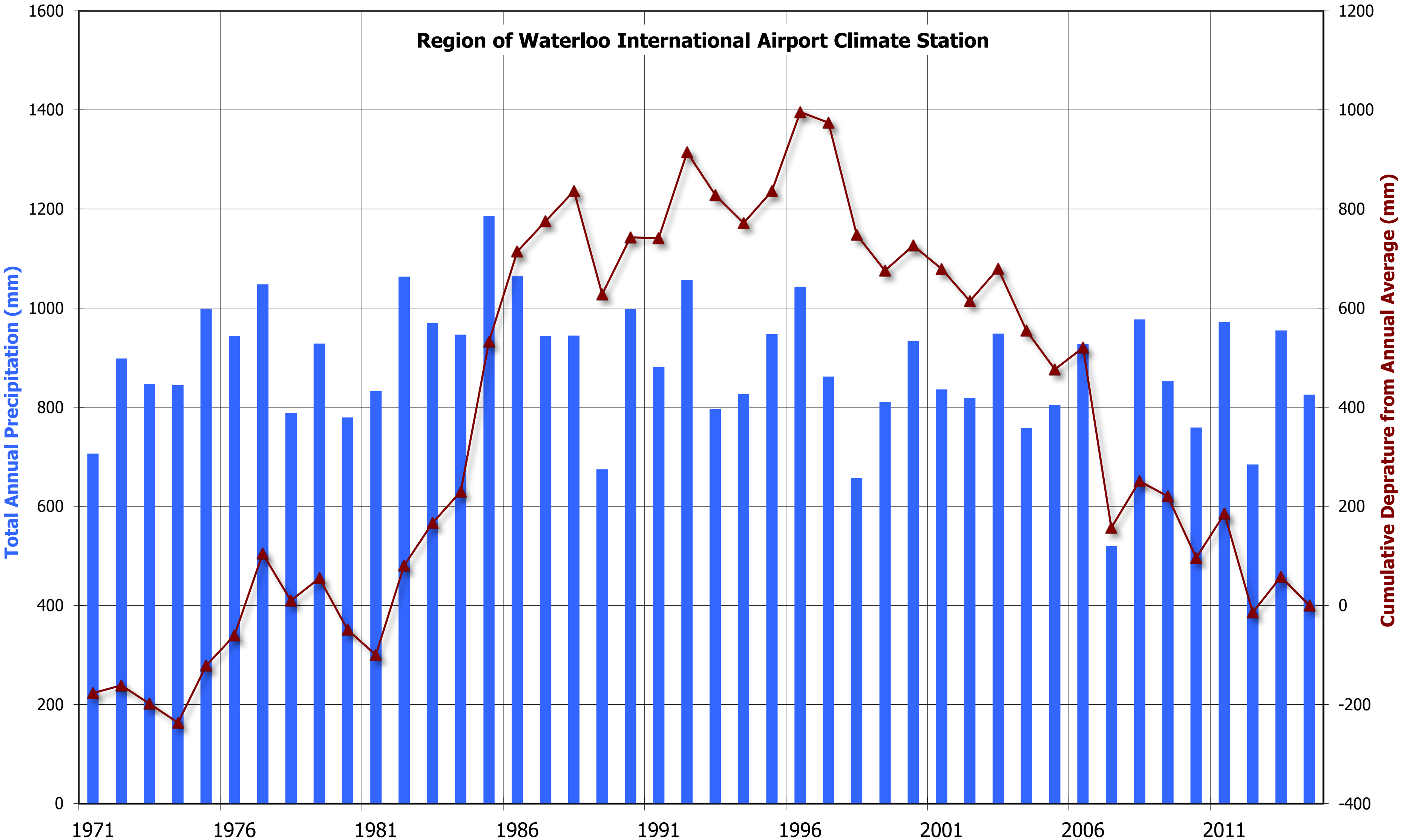


Gradients for Profile G: 004, 112, 109, 110/134, 113, 005/135, 114, 133
004
112
109
110
134
113
005 (I)
135
114
133
Groundwater Elevation (m amsl)
329.0
328.5
328.0
327.5
327.0
326.5
326.0
325.5
325.0
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014

Appendix E

Climate Monitoring 1971 – 2014

Annual Precipitation & Cumulative Departure from Annual Average - 1971 to 2014



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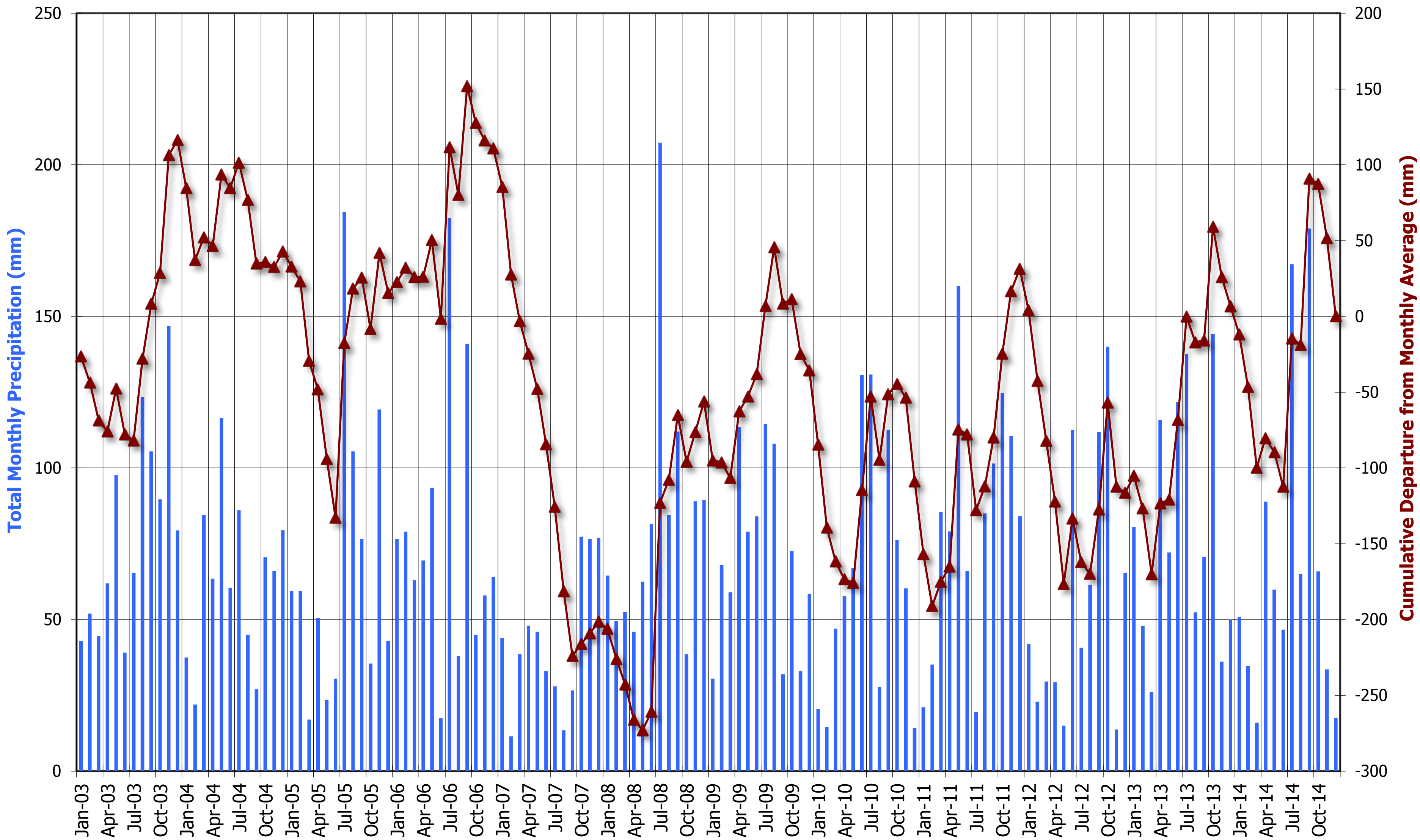
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Graph E 1**

Monthly Precipitation & Cumulative Departure from Monthly Average - 2003 to 2014



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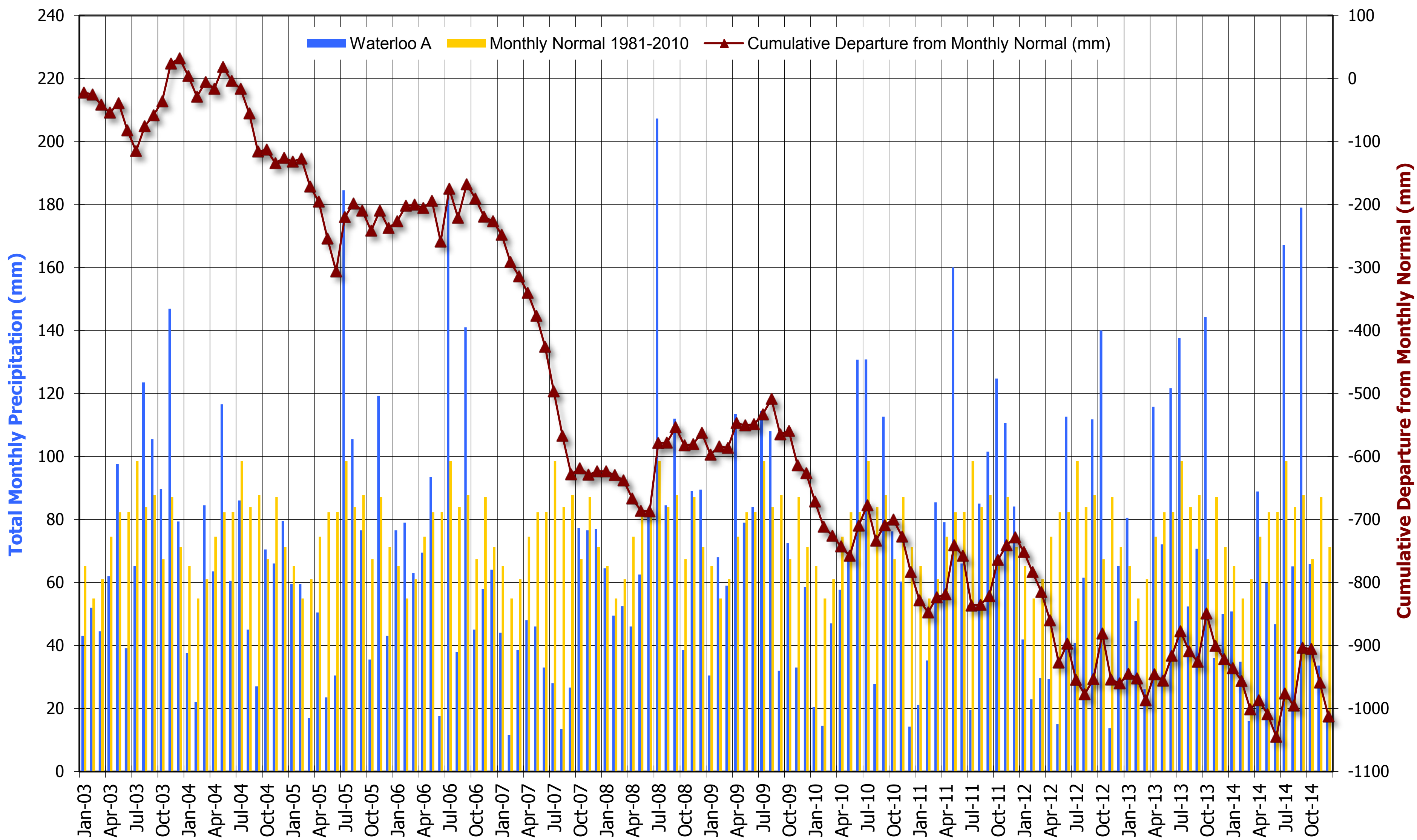
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Graph E 2**

Monthly Precipitation & Cumulative Departure from Monthly Normal - 2003 to 2014



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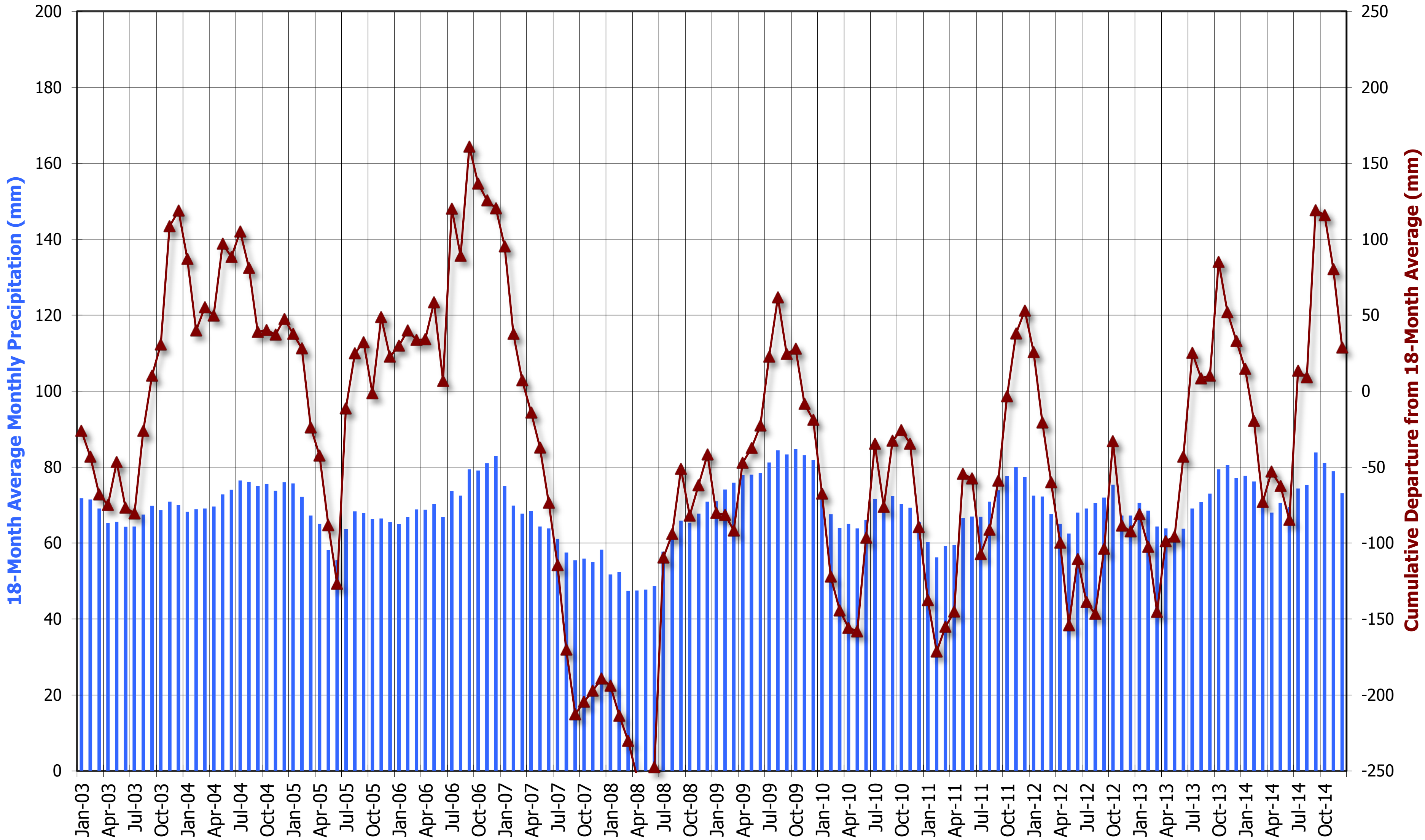
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Graph E 3**

18-Month Average Monthly Precipitation & Cumulative Departure from 18-Month Average - 2003 to 2014



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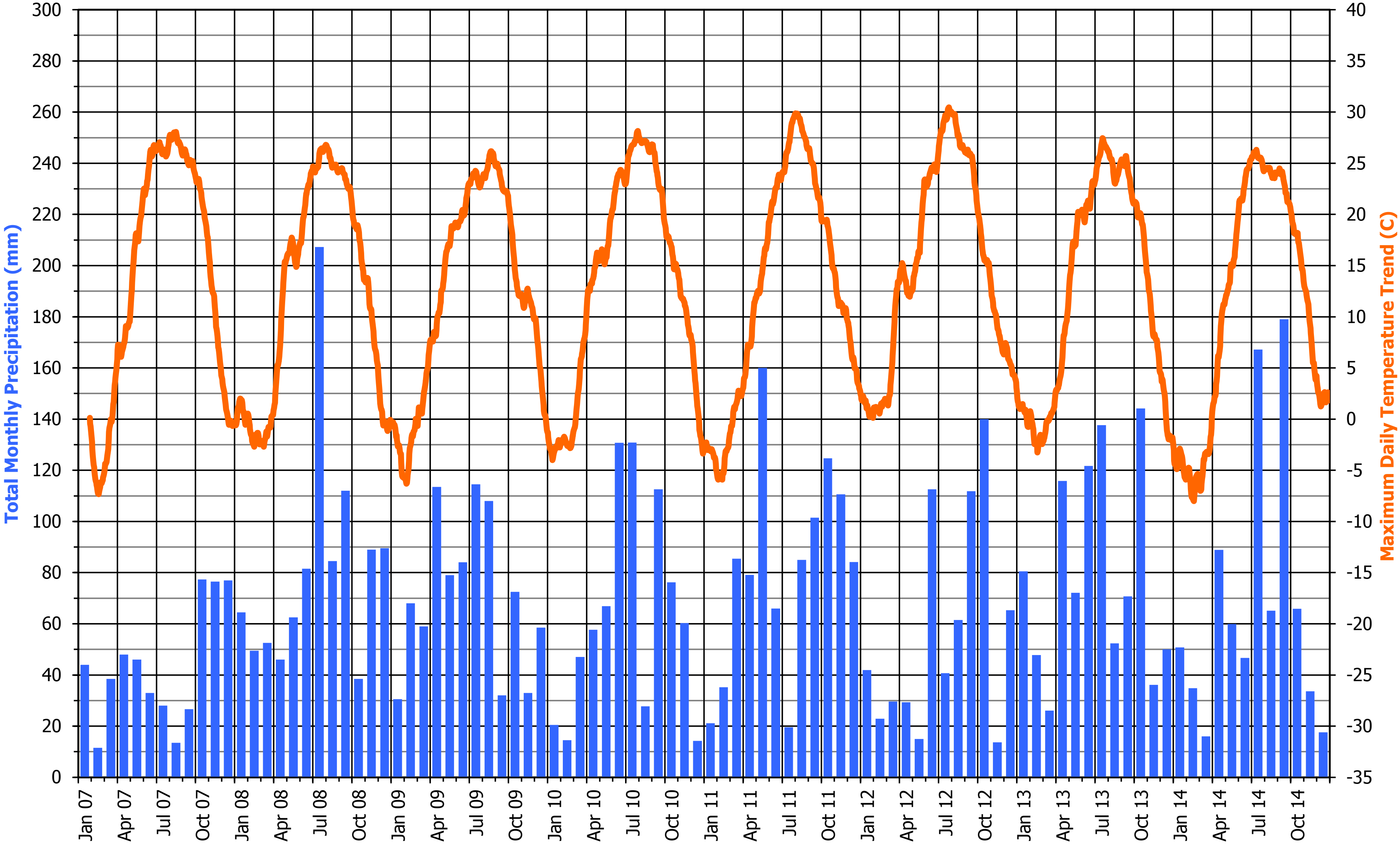
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014

Graph E 4

Monthly Precipitation & Maximum Daily Temperature Trend: Waterloo Airport (January 2007 to December 2014)



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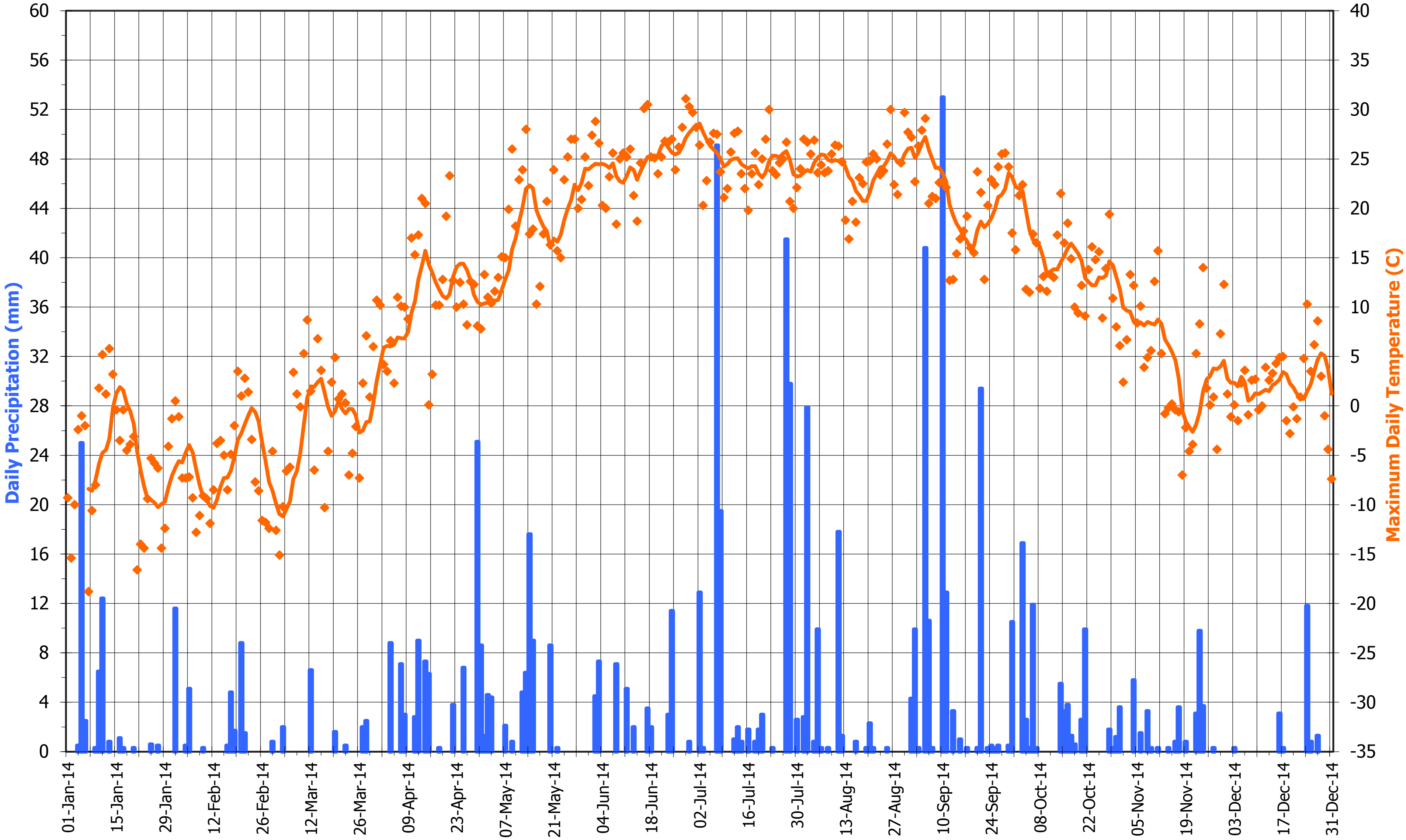
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Graph E 5**

Daily Precipitation & Maximum Daily Temperature: Waterloo Airport (January to December 2014)



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Hanlon Creek Business Park - Groundwater Monitoring Program

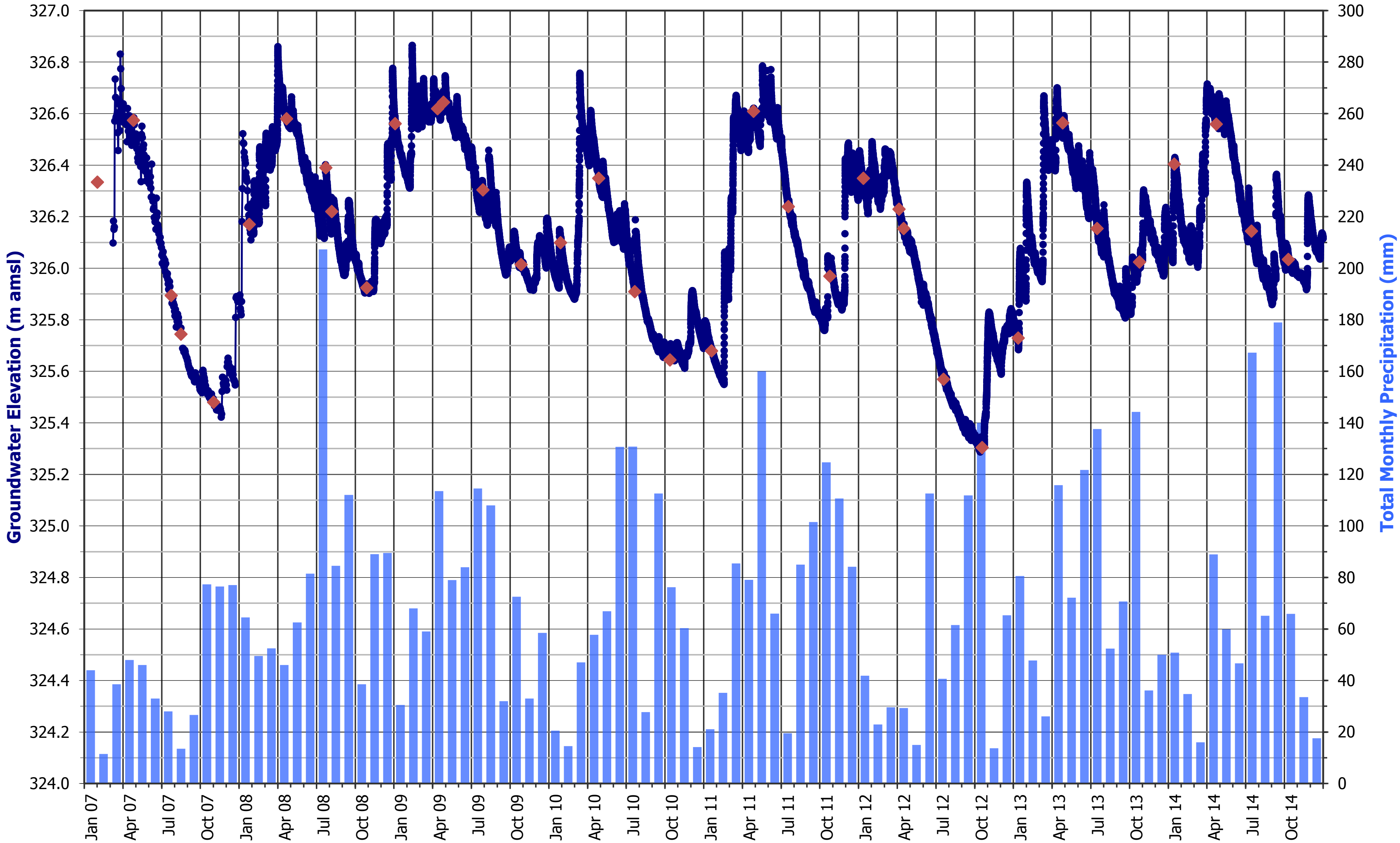
December 2014

Graph E 6

Appendix F

Downey Road PSW Groundwater Monitoring 2007 – 2014

Groundwater Elevation & Precipitation - MW003 (March 07 to December 14)



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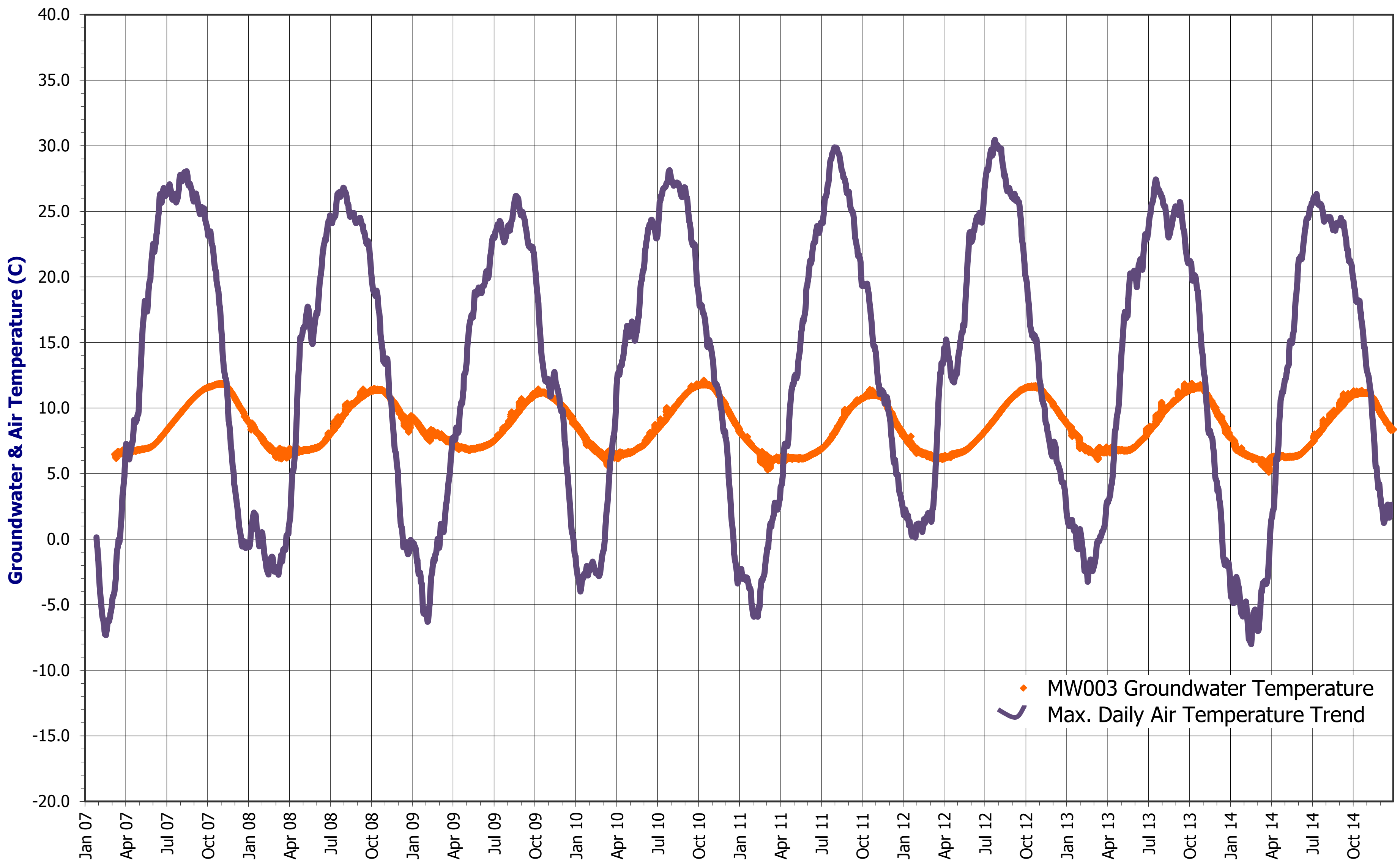
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 3 - Downey Rd. PSW** **Graph F 1**

Groundwater & Maximum Daily Air Temperature - MW003 (March 07 to December 14)



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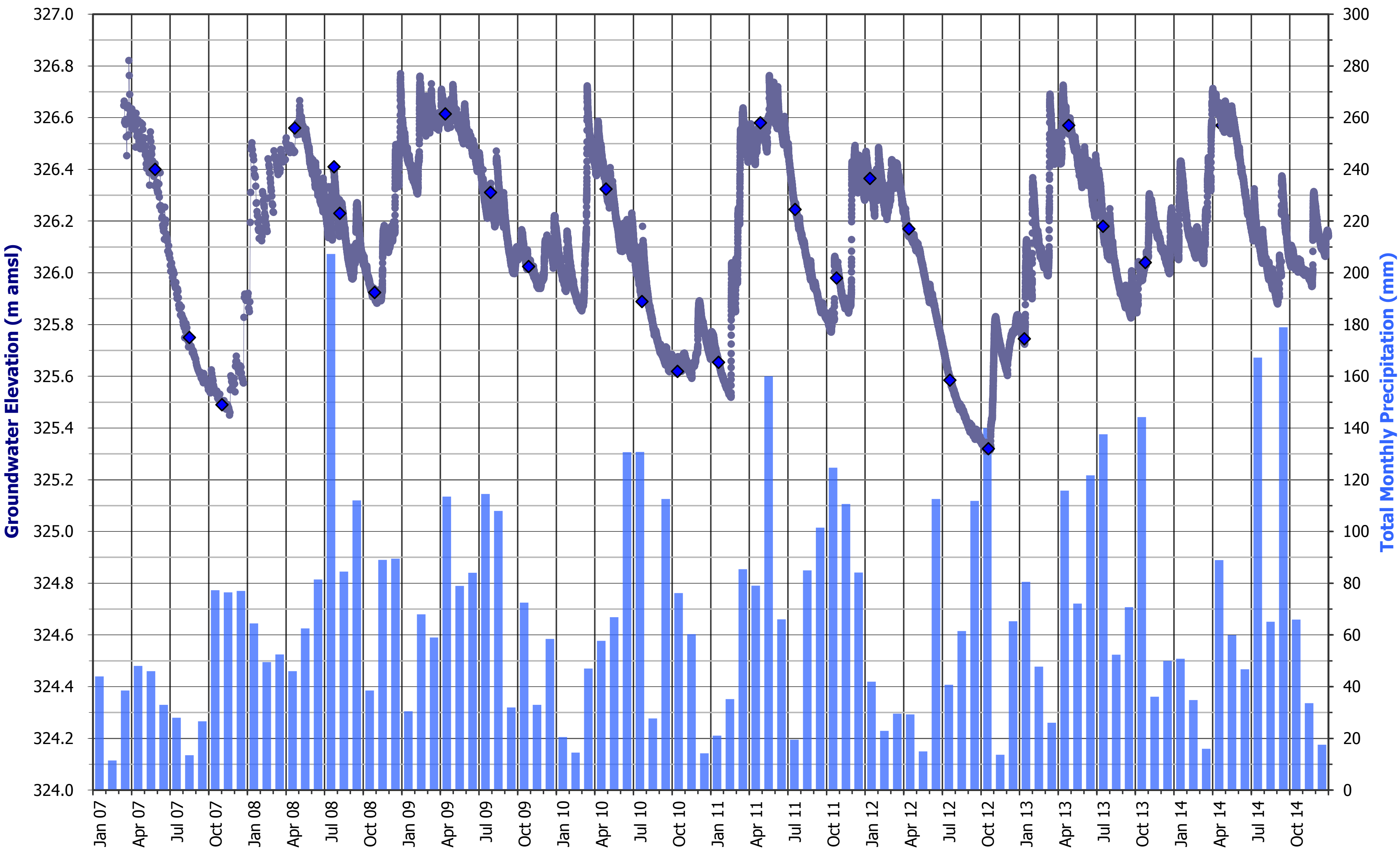
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 3 - Downey Rd. PSW** **Graph F 1a**

Groundwater Elevation & Precipitation - PZ-9D (March 07 to December 14)



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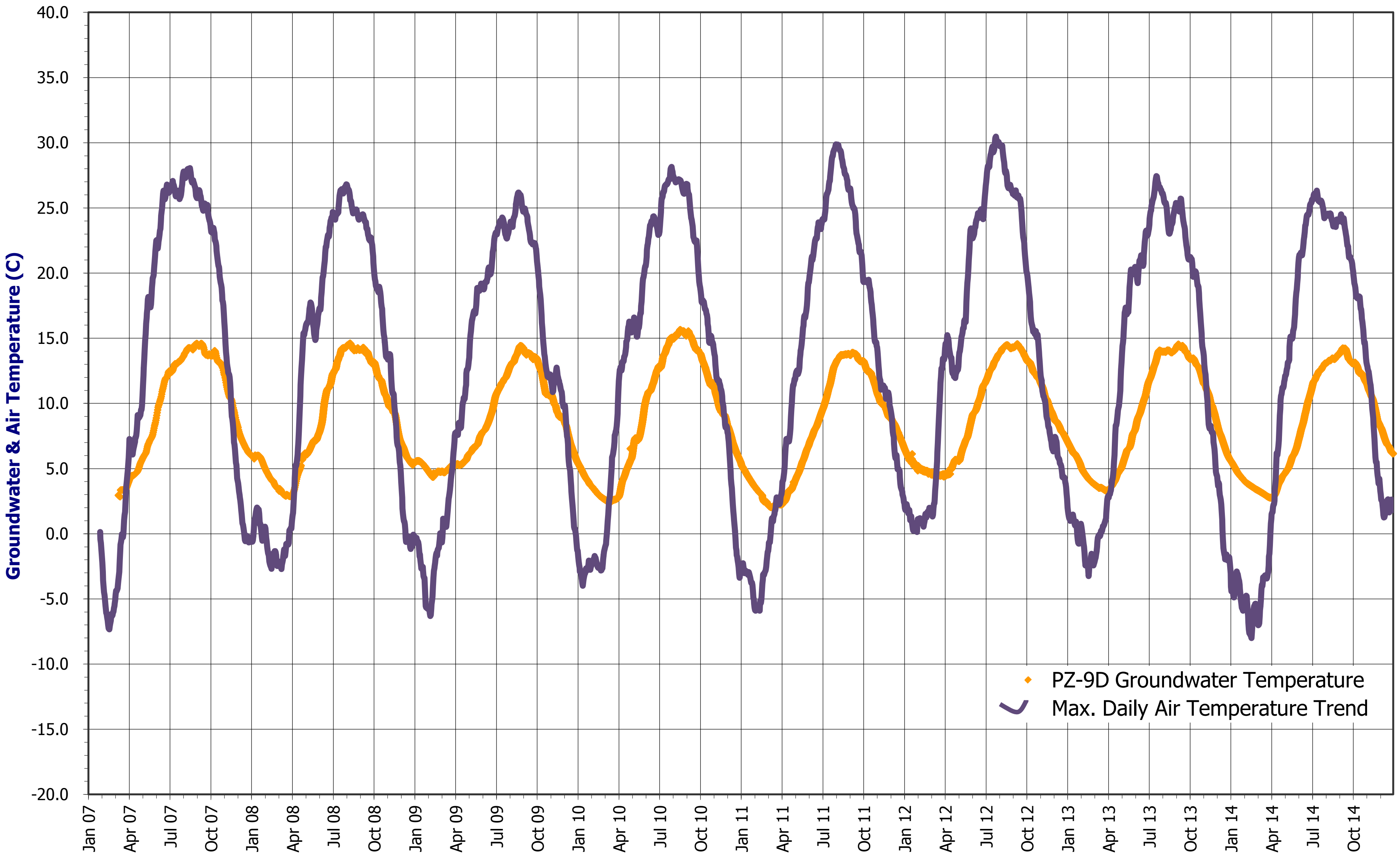
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 3 - Downey Rd. PSW** **Graph F 2**

Groundwater & Maximum Daily Air Temperature - PZ-9D (March 07 to December 14)



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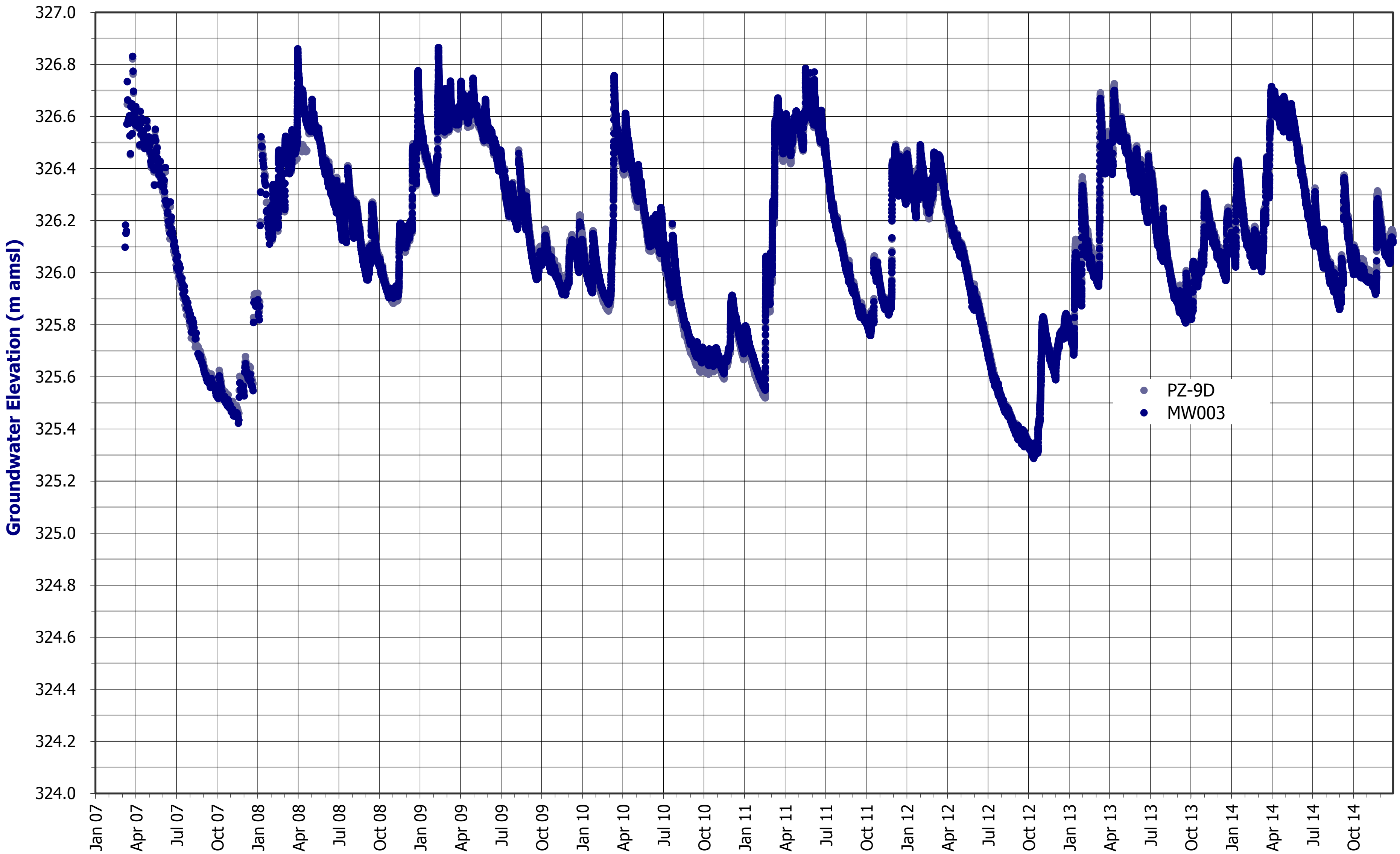
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 3 - Downey Rd. PSW** **Graph F 2a**

Groundwater Elevation: MW003 & PZ-9D (March 07 to December 14)



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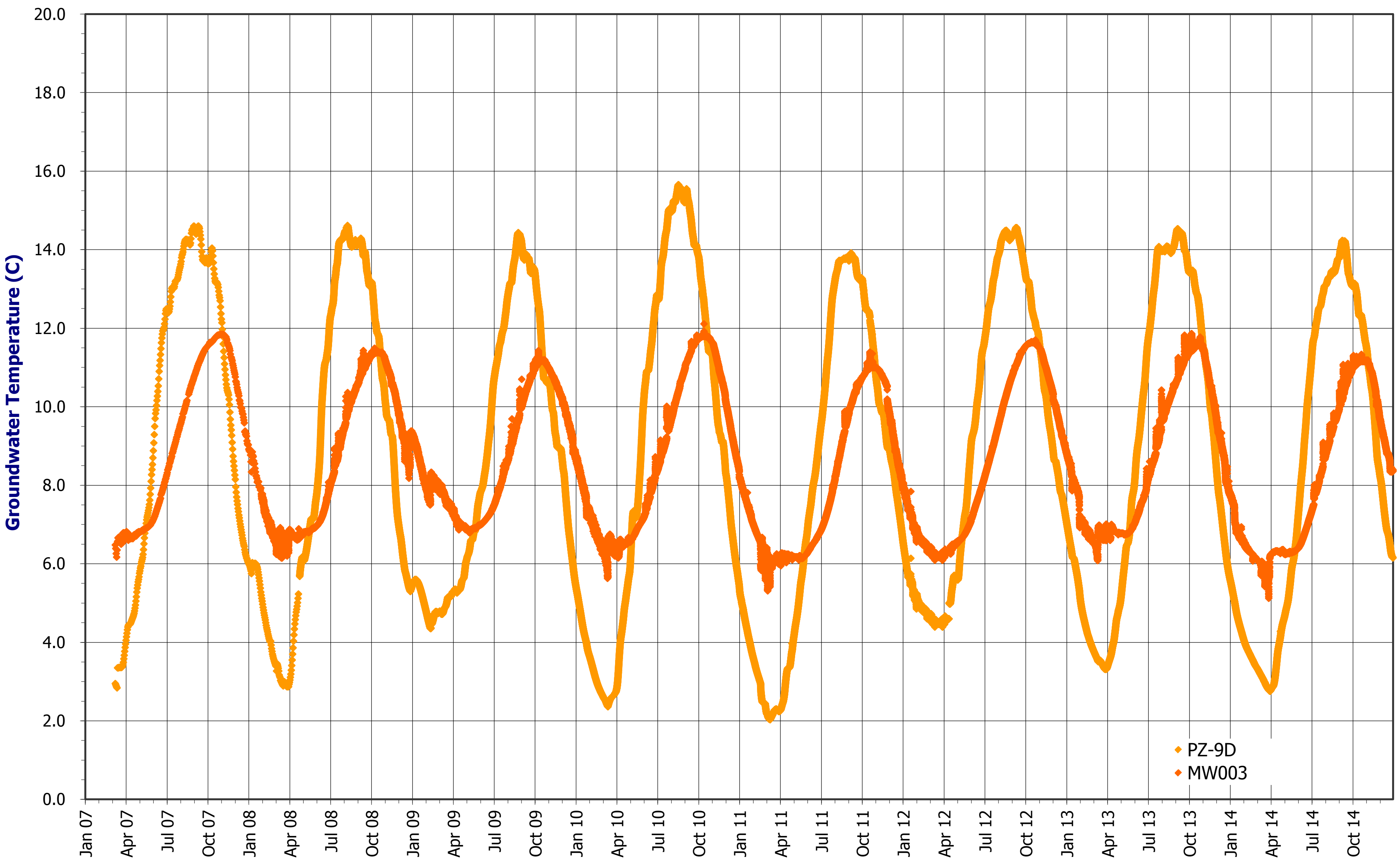
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 3 - Downey Rd. PSW** **Graph F 3**

Groundwater Temperature - MW003 & PZ-9D (March 07 to December 14)



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Hanlon Creek Business Park - Groundwater Monitoring Program

December 2013 **Phase 3 - Downey Rd. PSW** **Graph F 3a**

Appendix G

HCBP Core PSW Groundwater Monitoring 2007 – 2014

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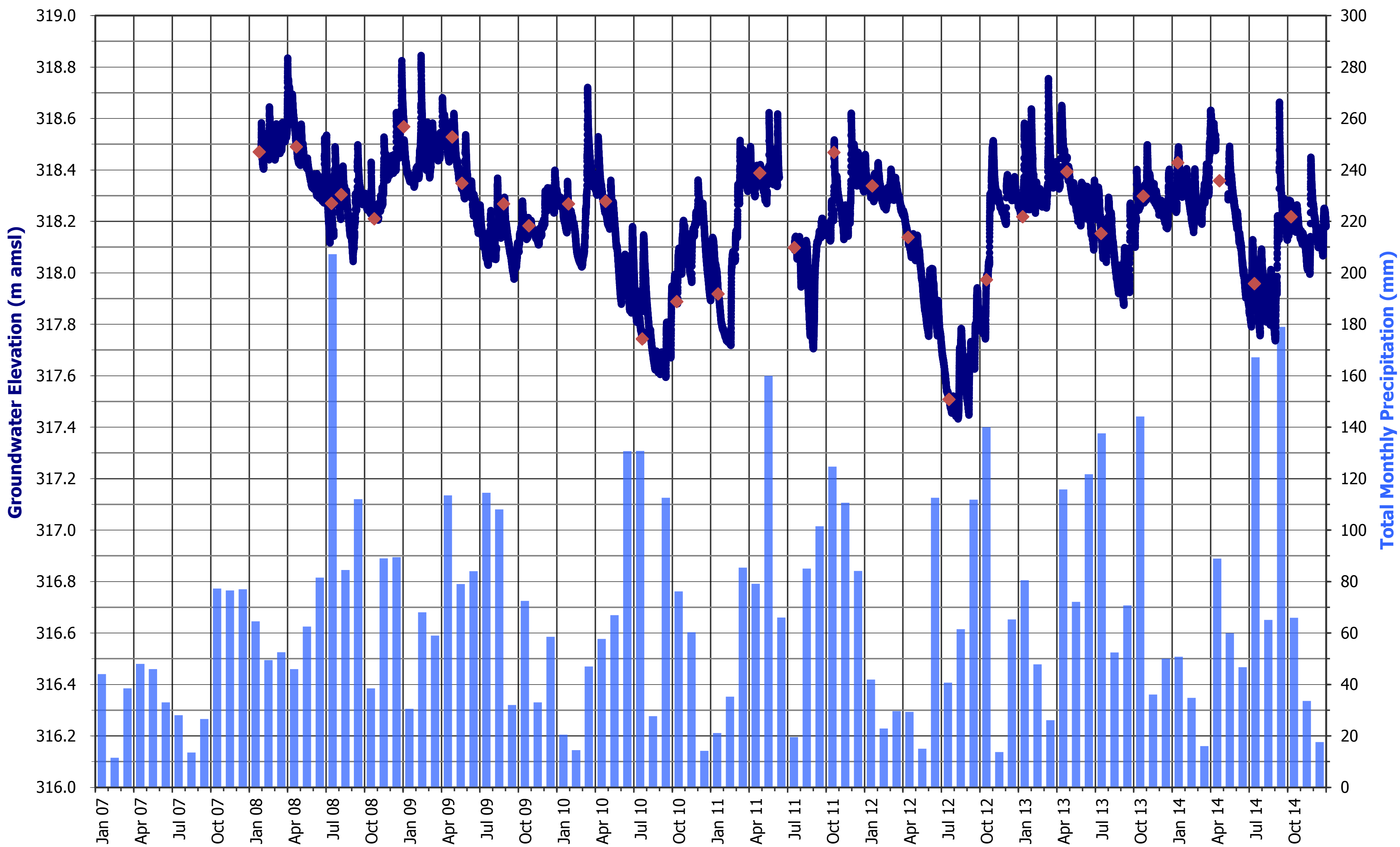
Groundwater Elevation & Precipitation - MW116A (January 08 to December 14)

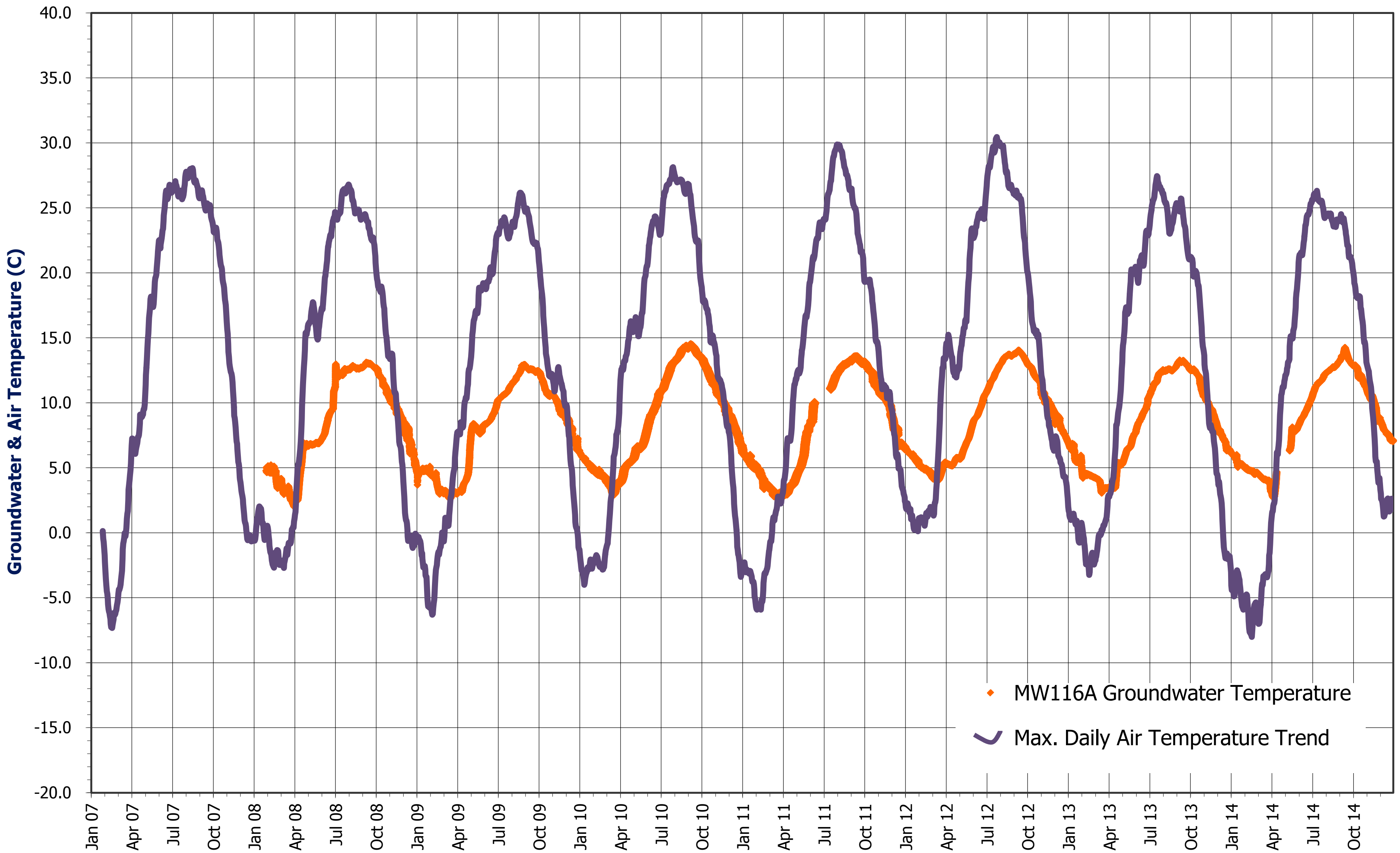


Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph G 1**

Groundwater & Maximum Daily Air Temperature - MW116A (January 08 to December 14)



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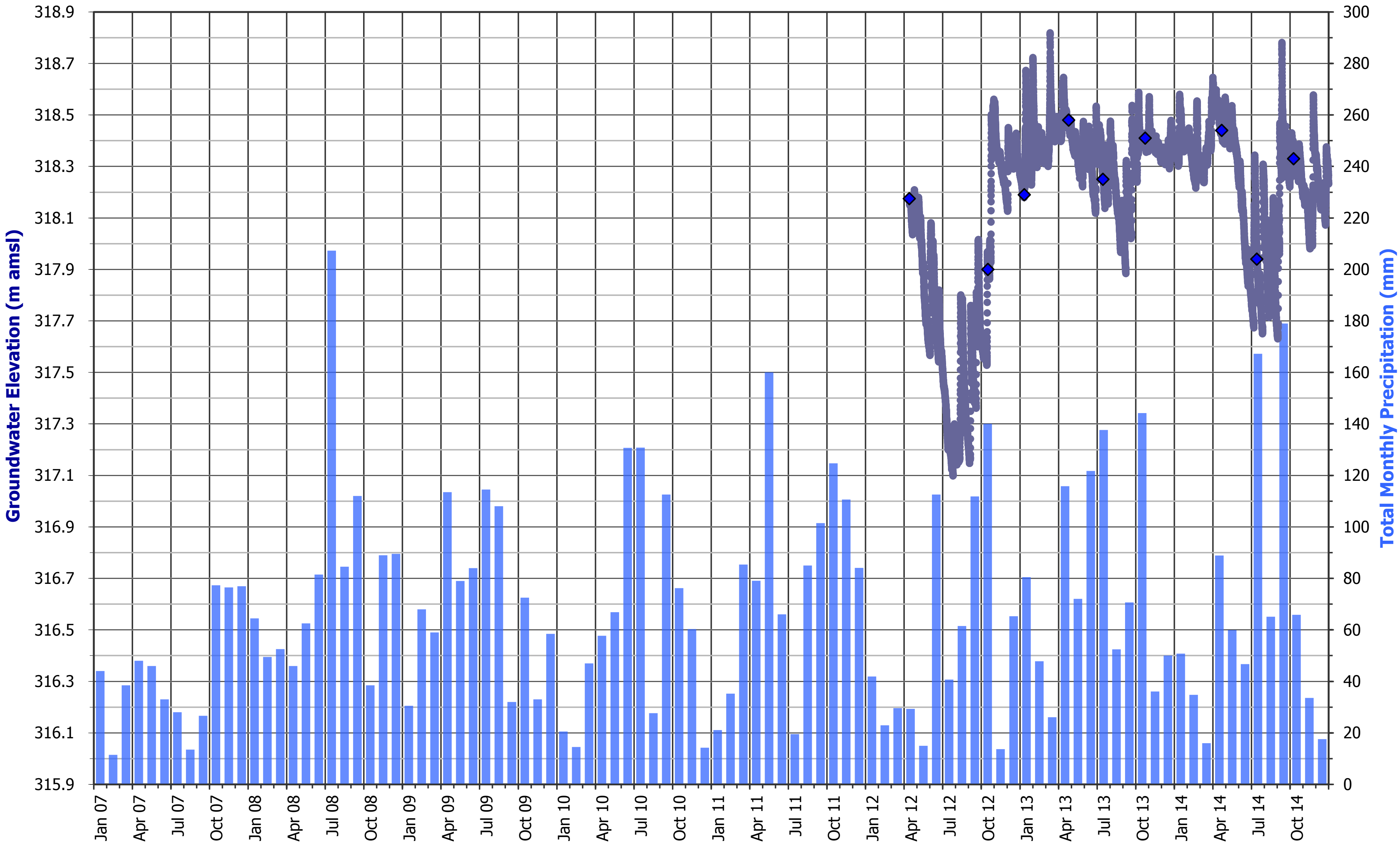
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph G 1a**

Groundwater Elevation & Precipitation - PZ-10D (April 12 to December 14)



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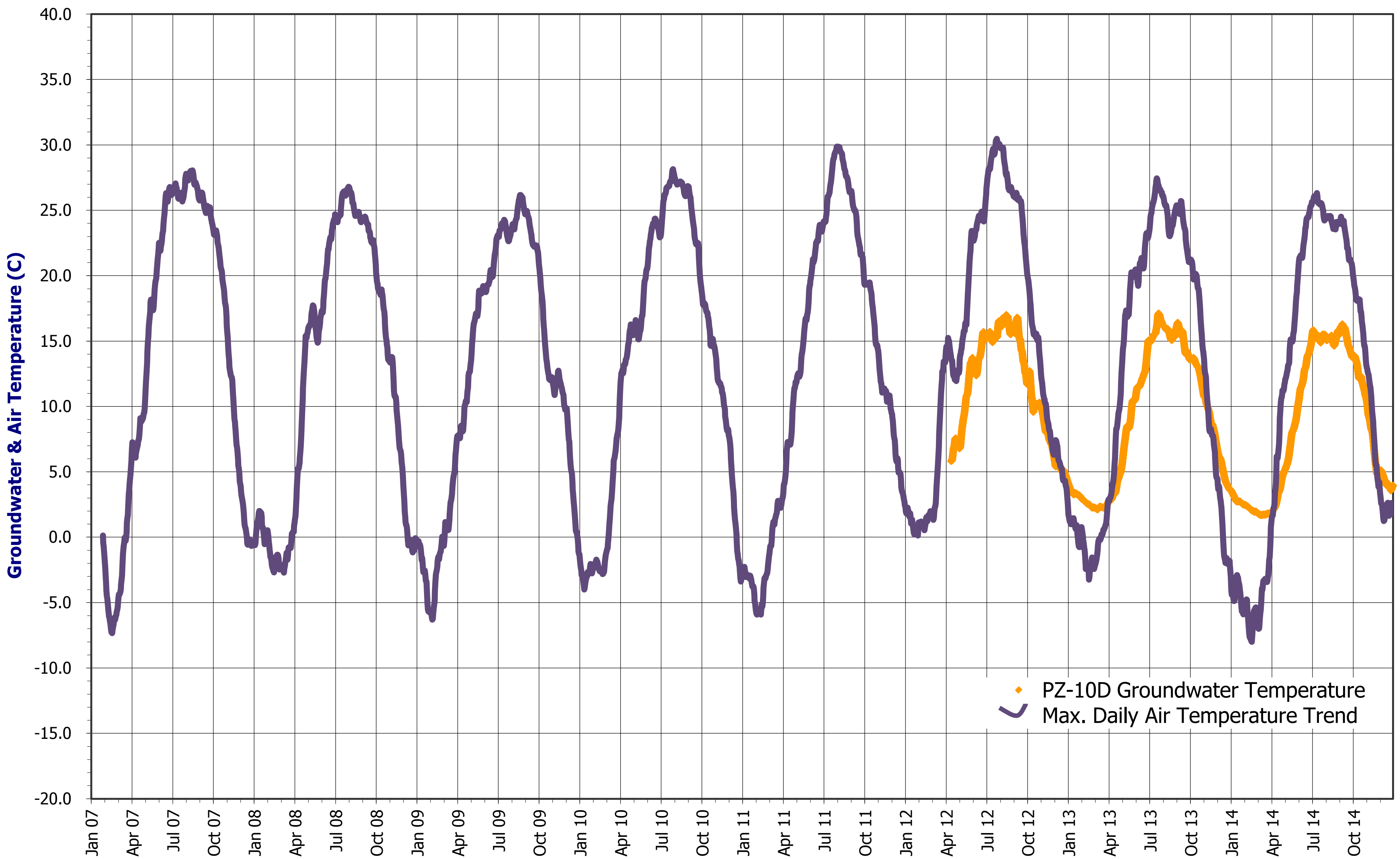
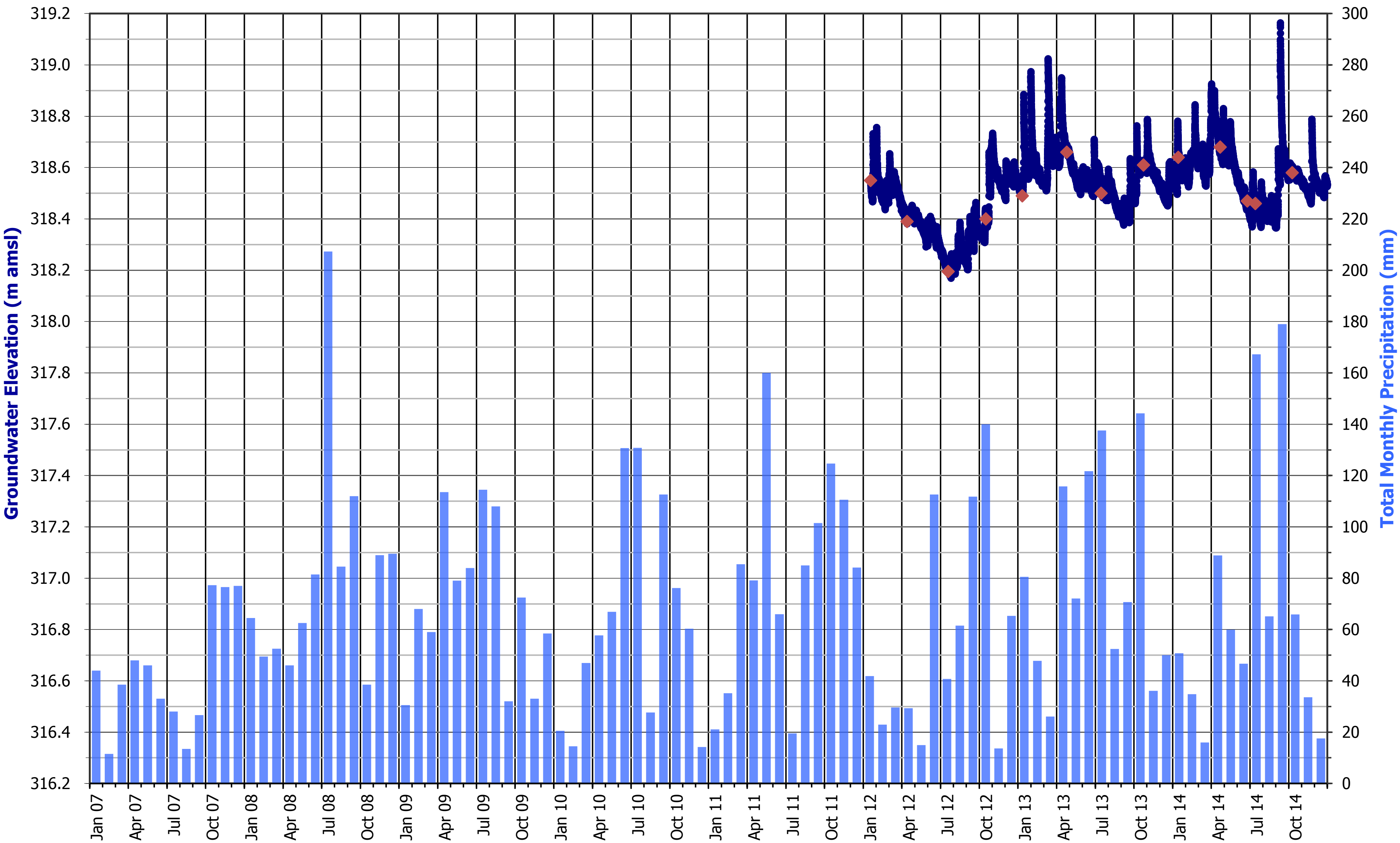
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph G 2**

Groundwater & Maximum Daily Air Temperature - PZ-10D (April 12 to December 14)



Groundwater Elevation & Precipitation - MW127 (January 12 to December 14)



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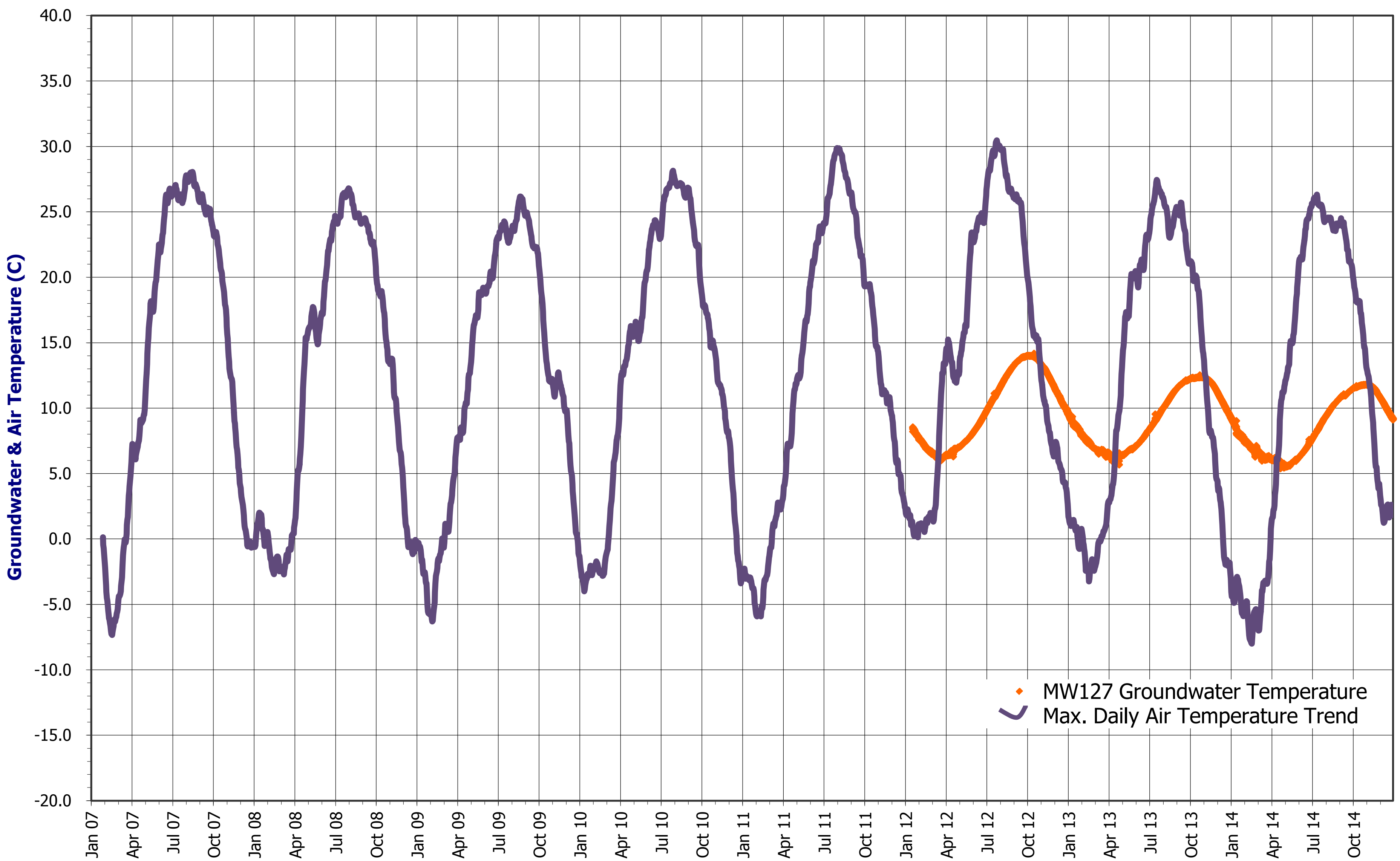
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph G 3**

Groundwater & Maximum Daily Air Temperature - MW127 (January 12 to December 14)



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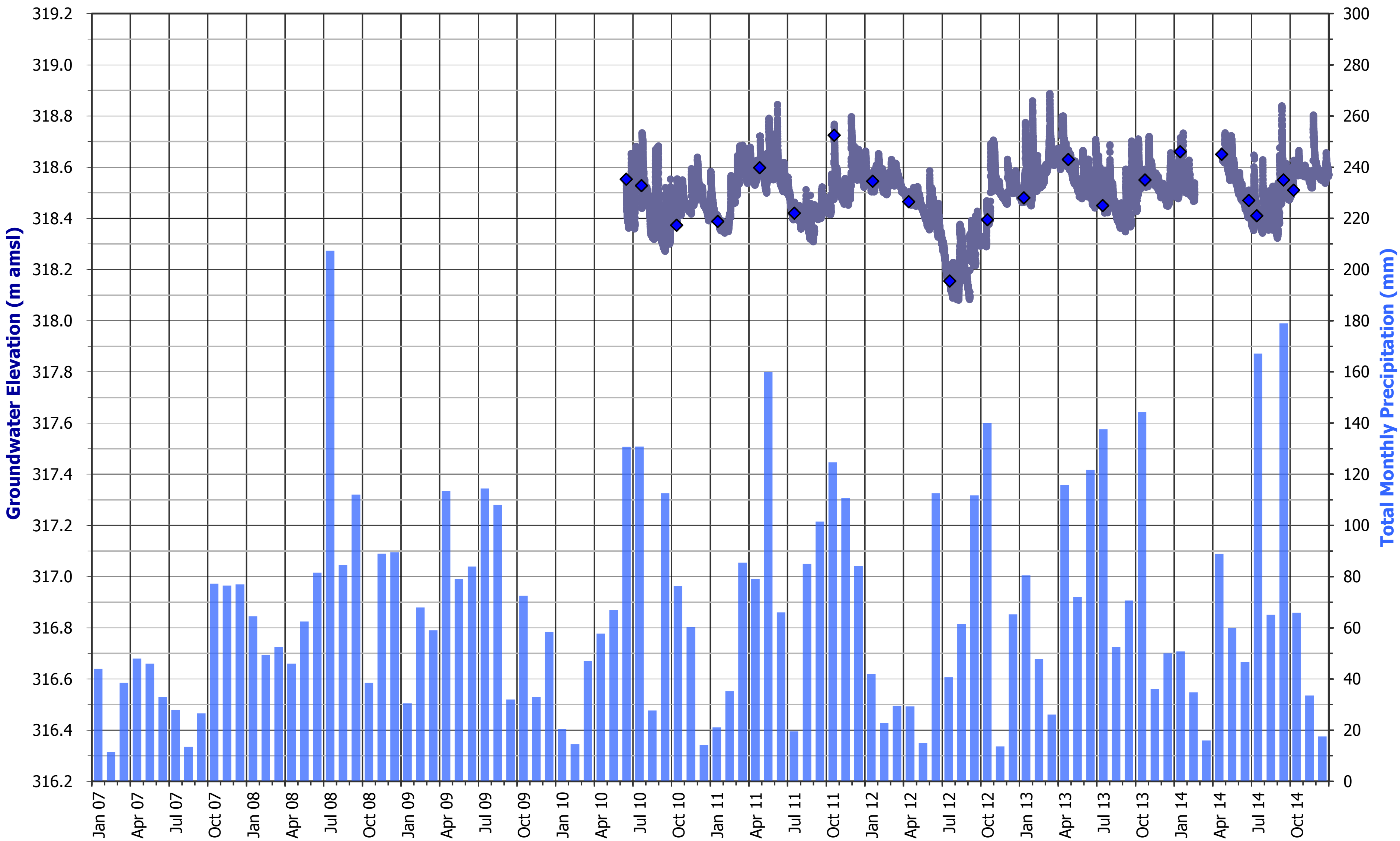
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014

Phase 1 - Core PSW **Graph G 3a**

Groundwater Elevation & Precipitation - PZ-8D (June 10 to December 14)



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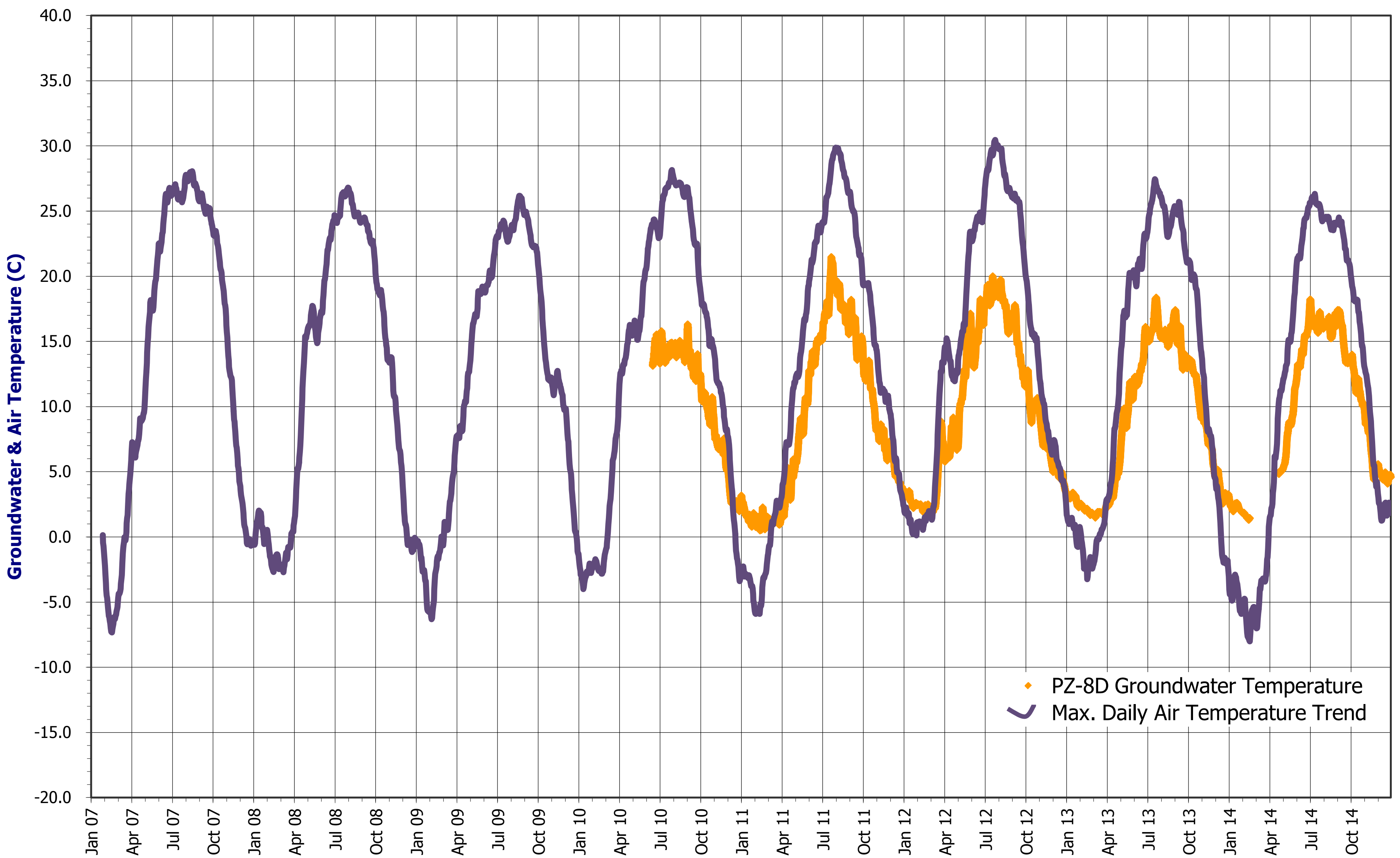
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph G 4**

Groundwater & Maximum Daily Air Temperature - PZ-8D (June 10 to December 14)



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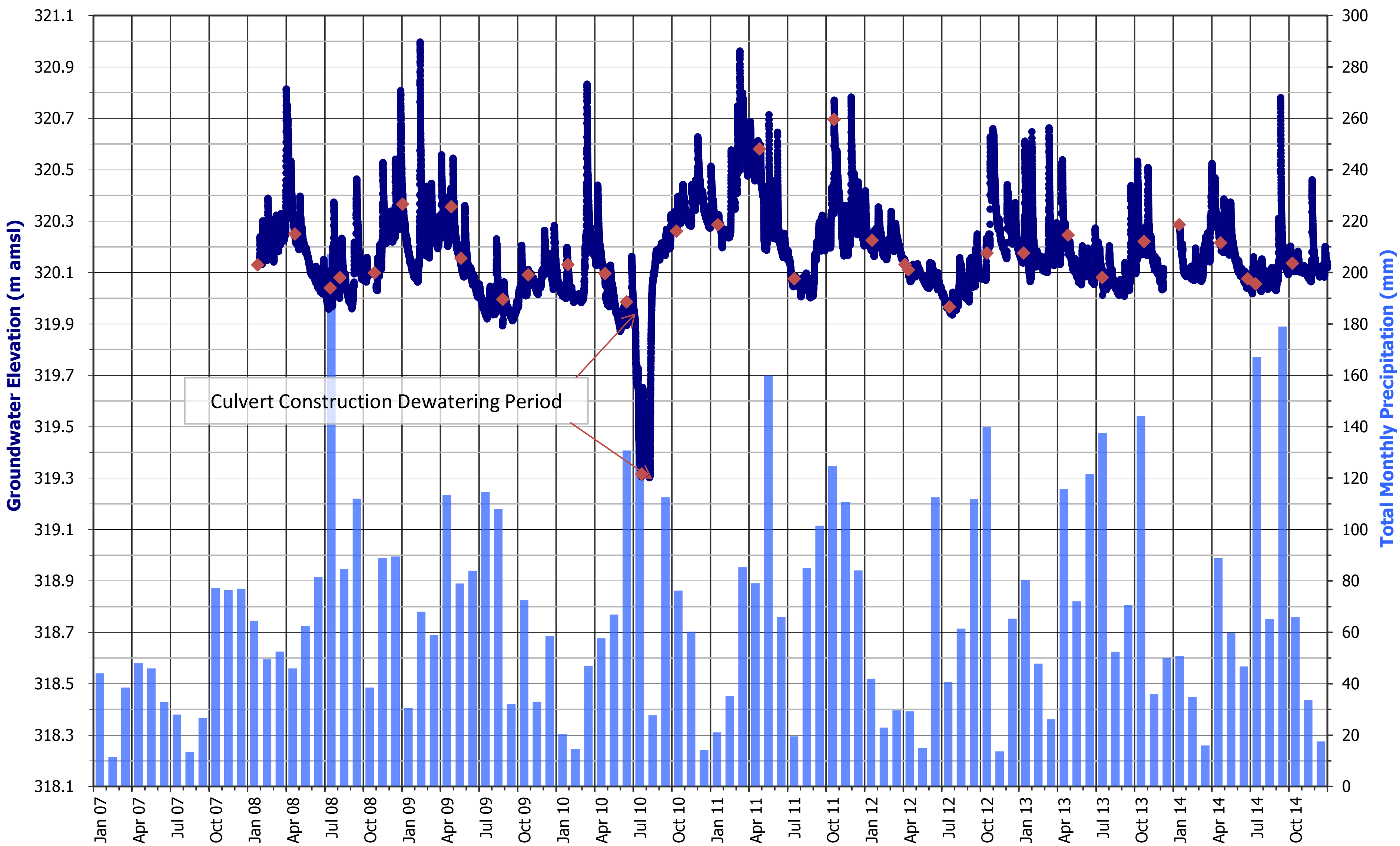
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph G 4a**

Groundwater Elevation & Precipitation - MW117A (January 08 to December 14)



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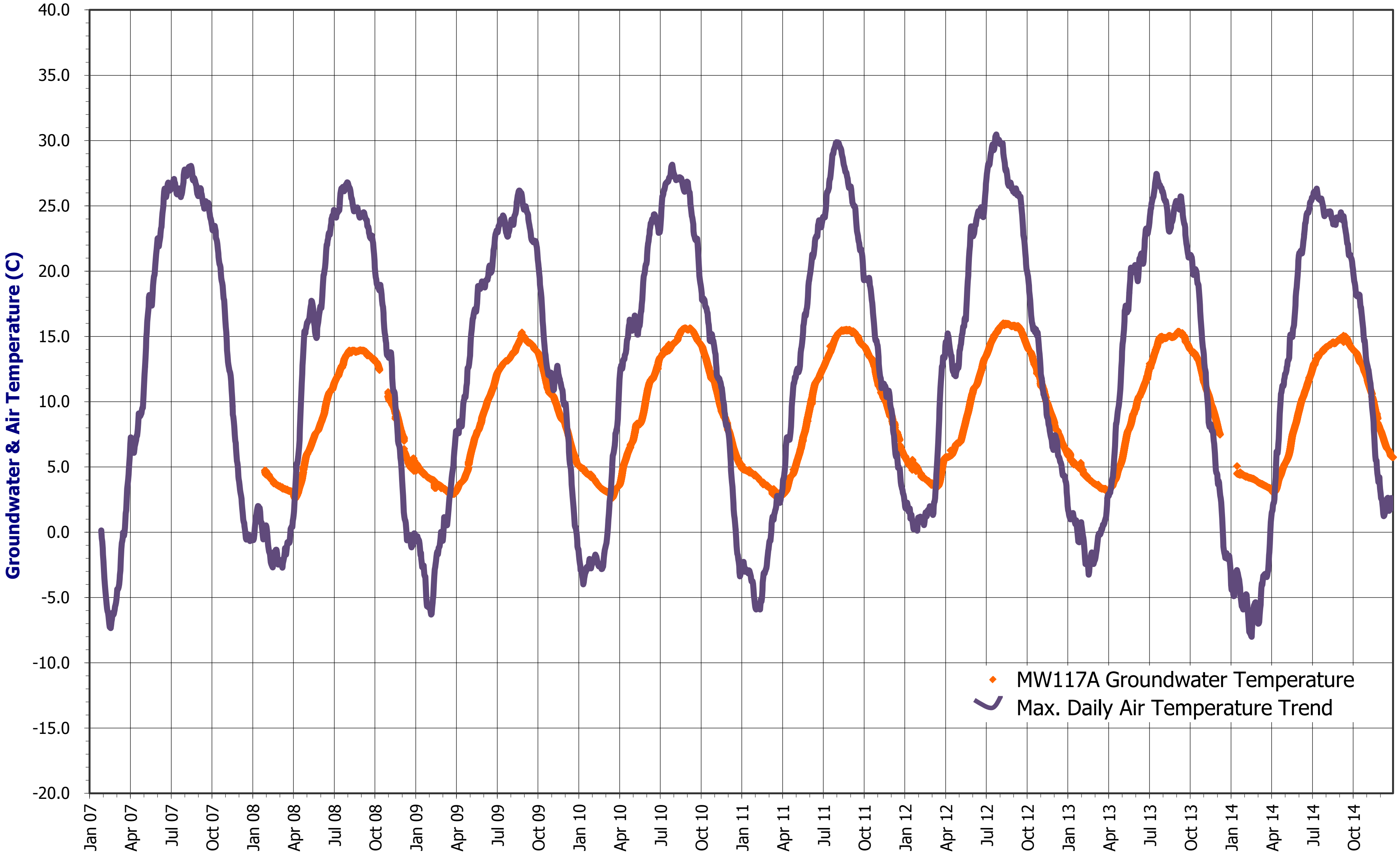
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph G 5**

Groundwater & Maximum Daily Air Temperature - MW117A (January 08 to December 14)



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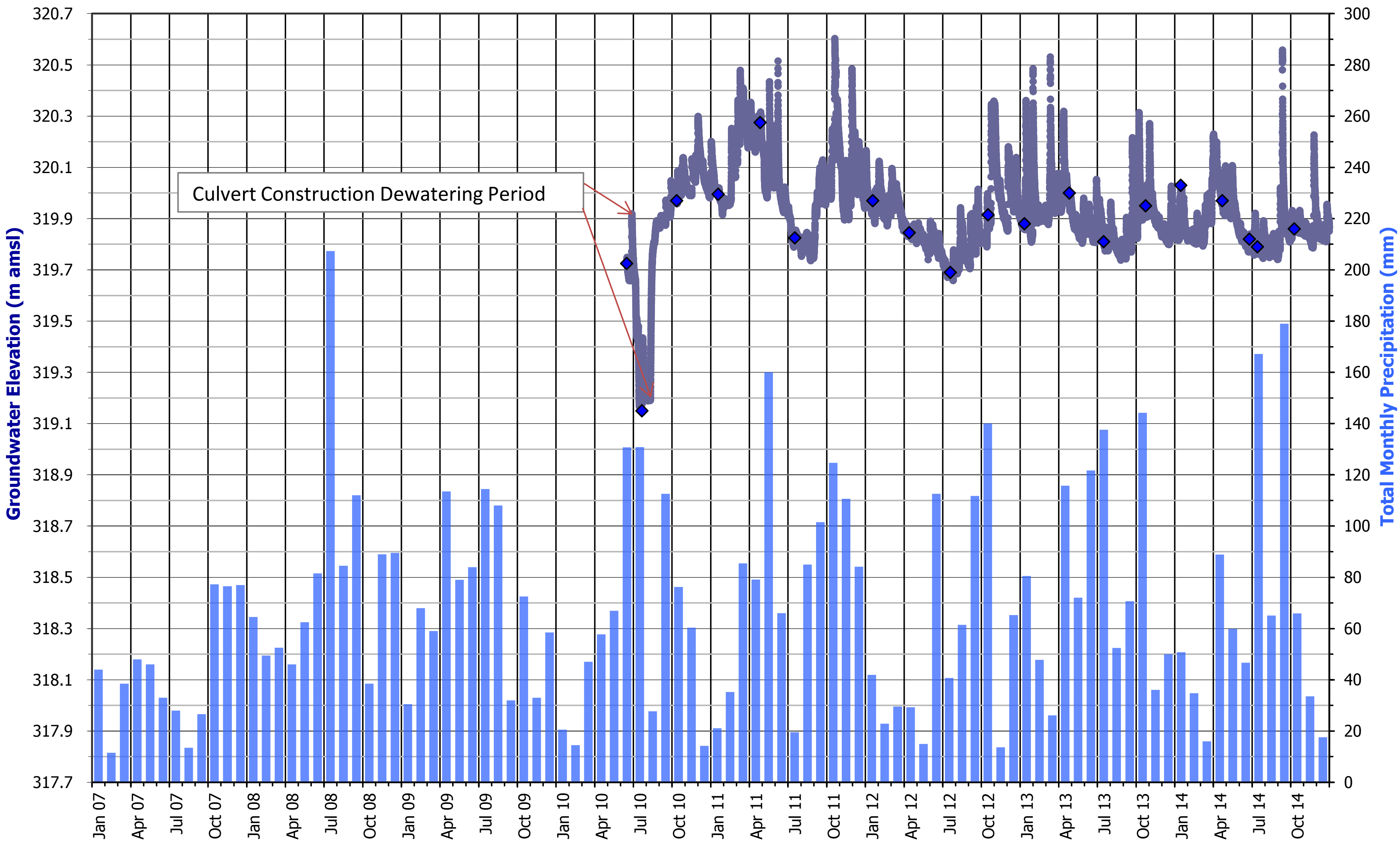
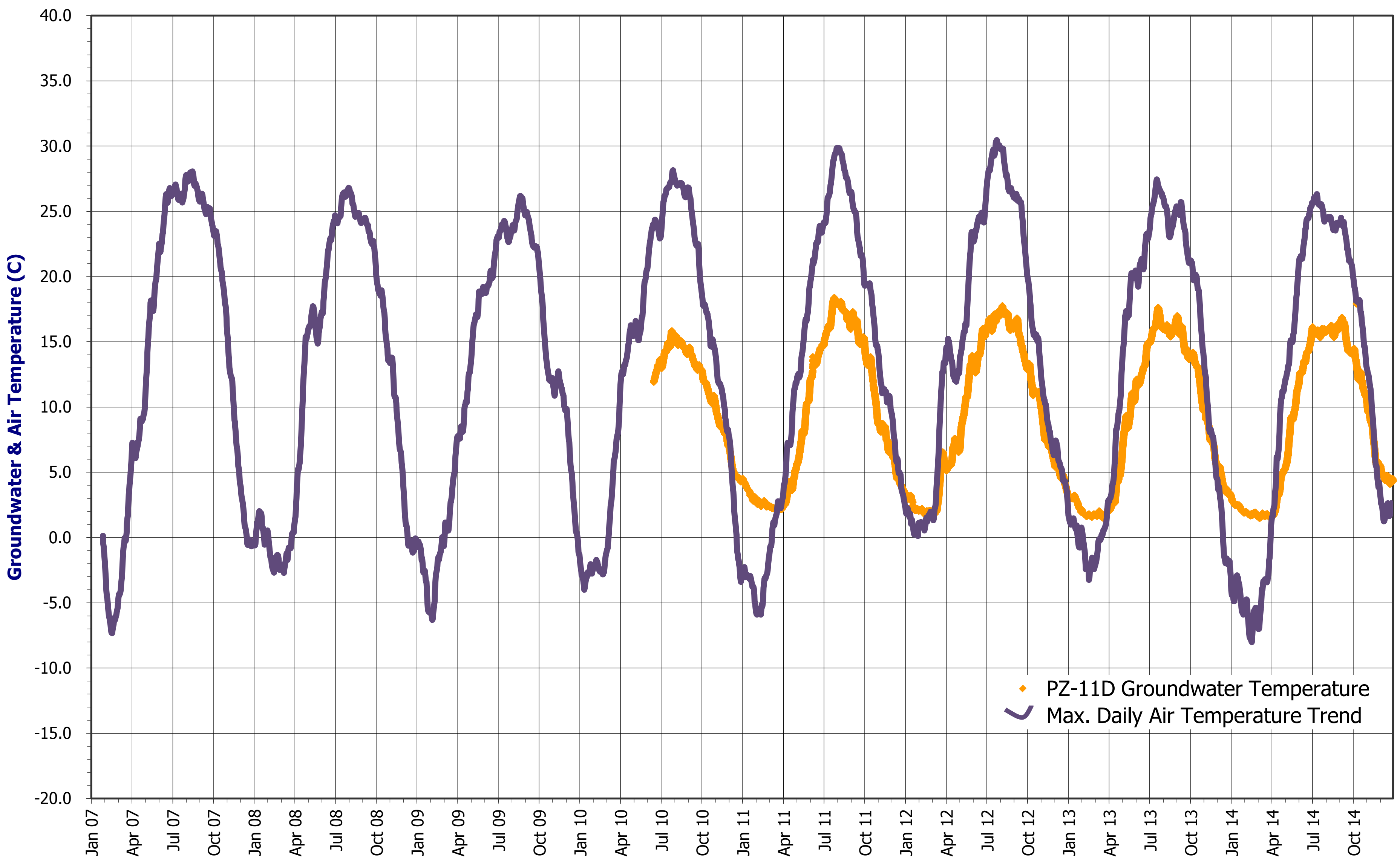
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph G 5a**

Groundwater Elevation & Precipitation - PZ-11D (June 10 to December 14)



Groundwater & Maximum Daily Air Temperature - PZ-11D (June 10 to December 14)



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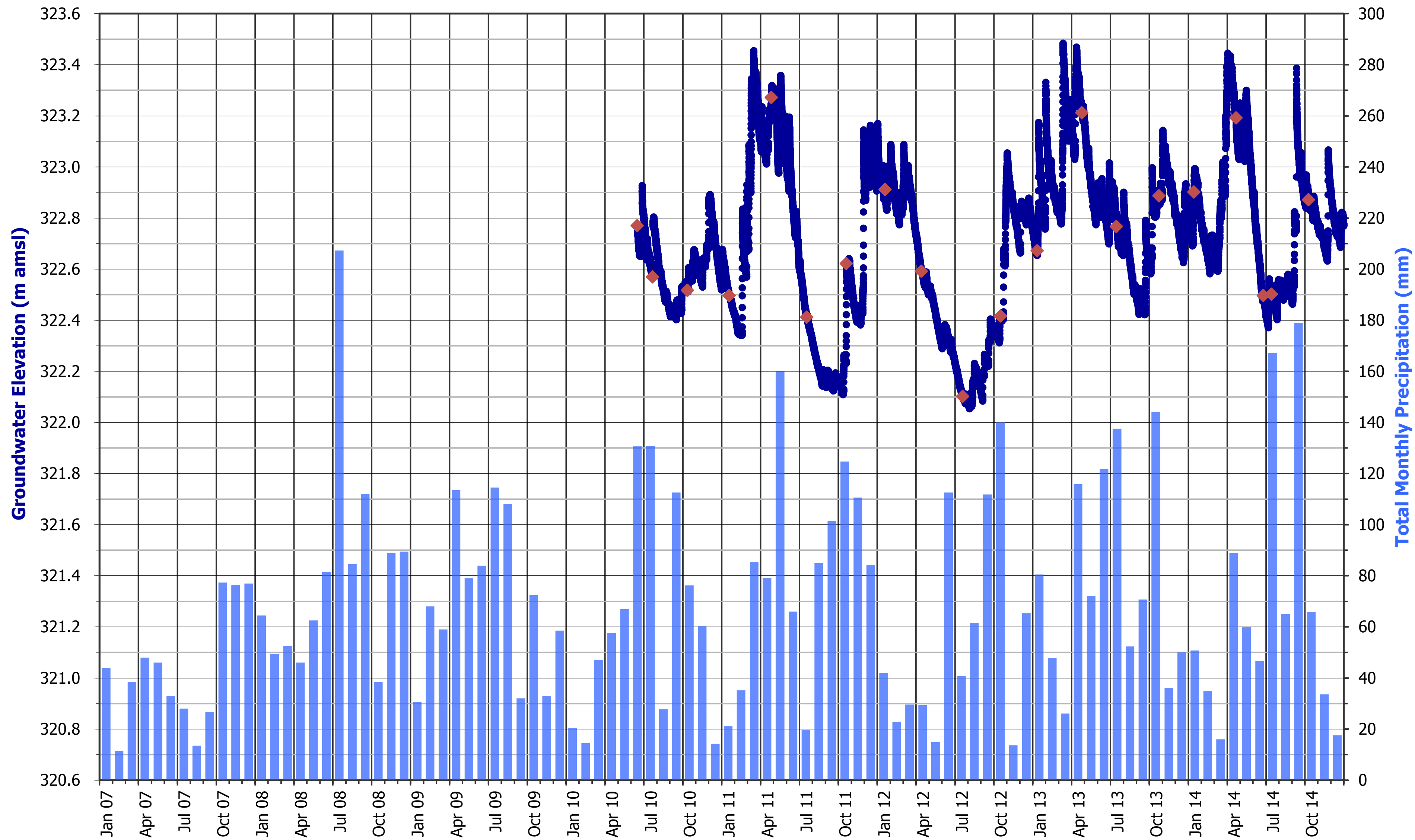
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 | **Phase 1 - Core PSW** | **Graph G 6a**

Groundwater Elevation & Precipitation - MW103 (June 10 to December 14)



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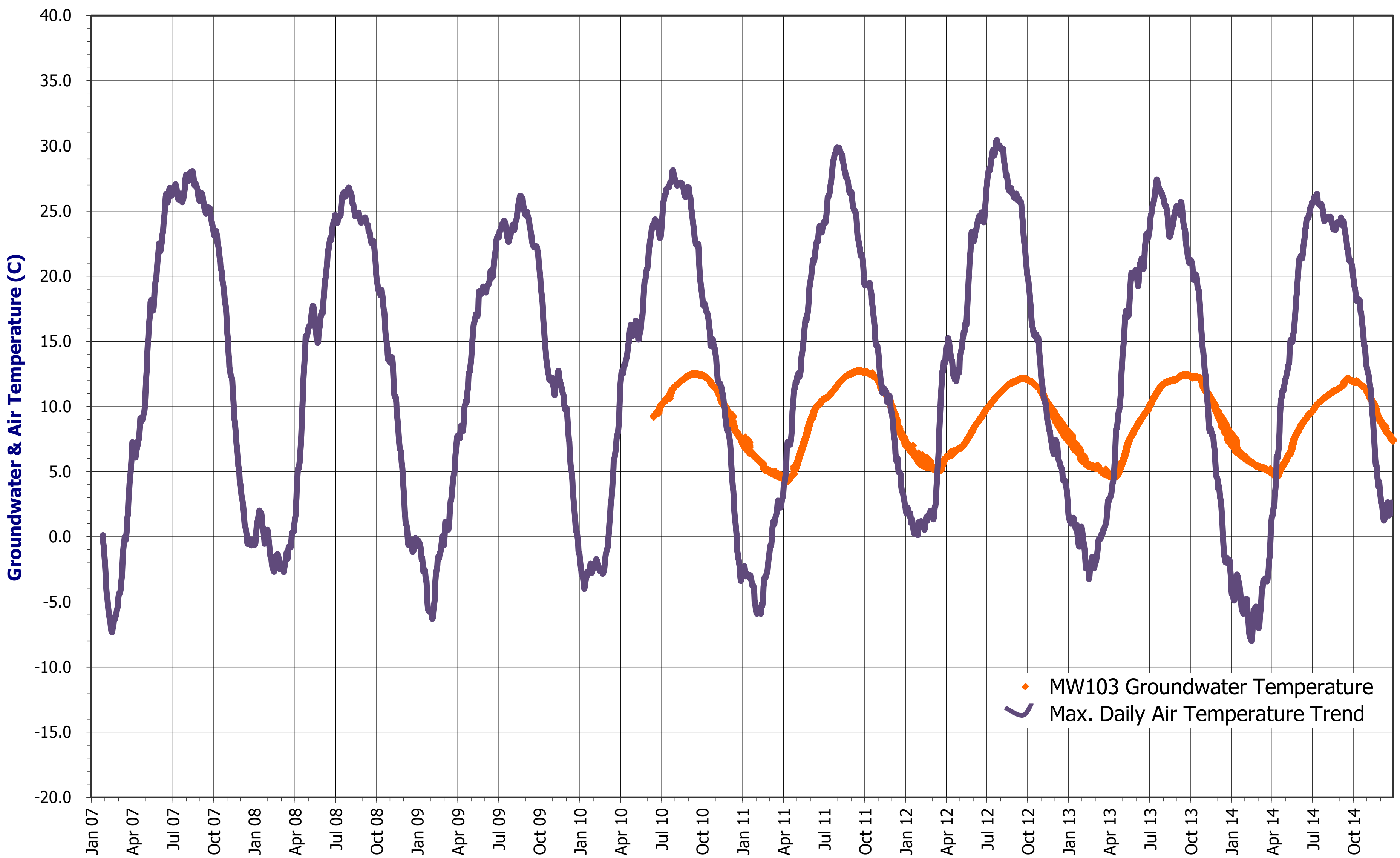
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph G 7**

Groundwater & Maximum Daily Air Temperature - MW103 (June 10 to December 14)



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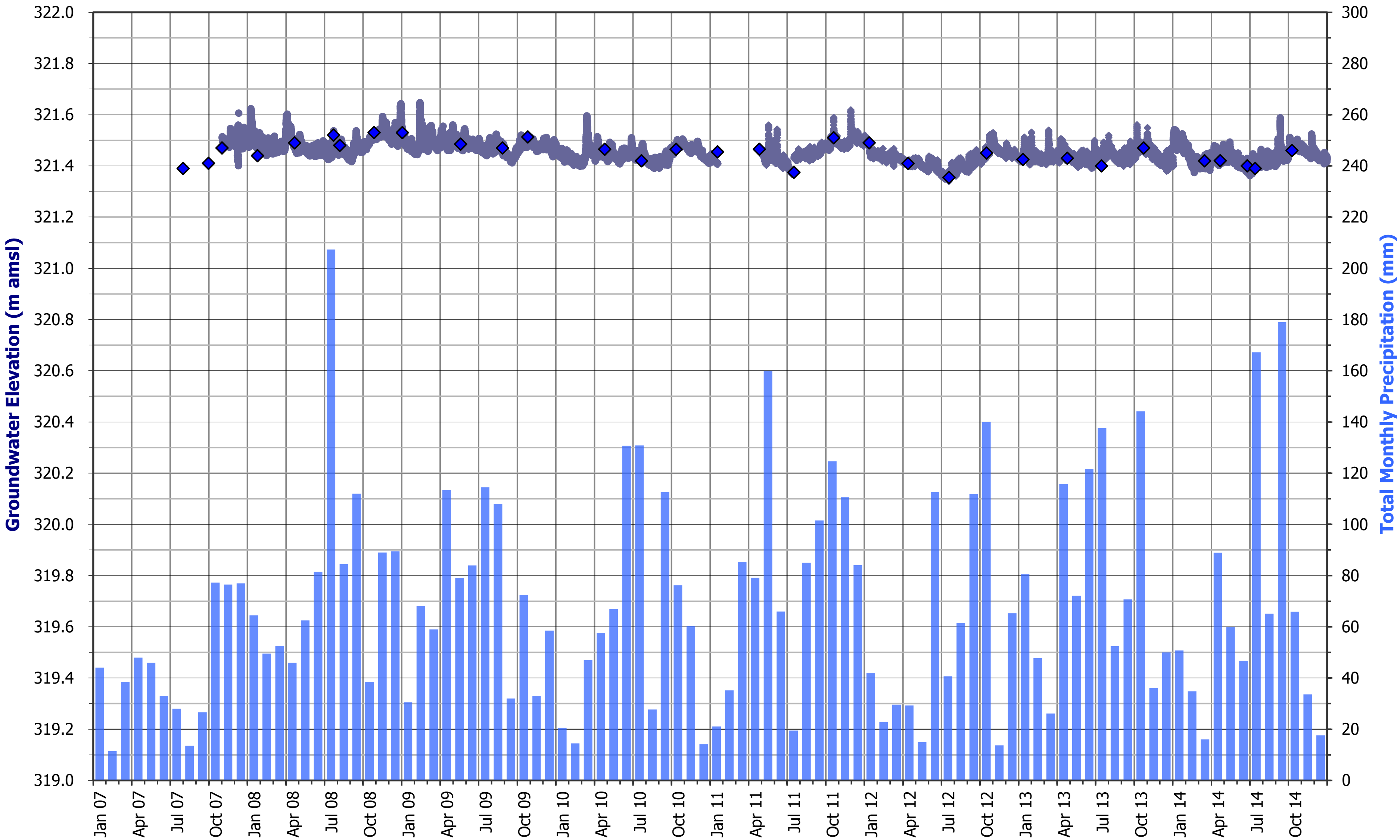
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014

Phase 1 - Core PSW Graph G 7a

Groundwater Elevation & Precipitation - PZ-7D (August 07 to December 14)



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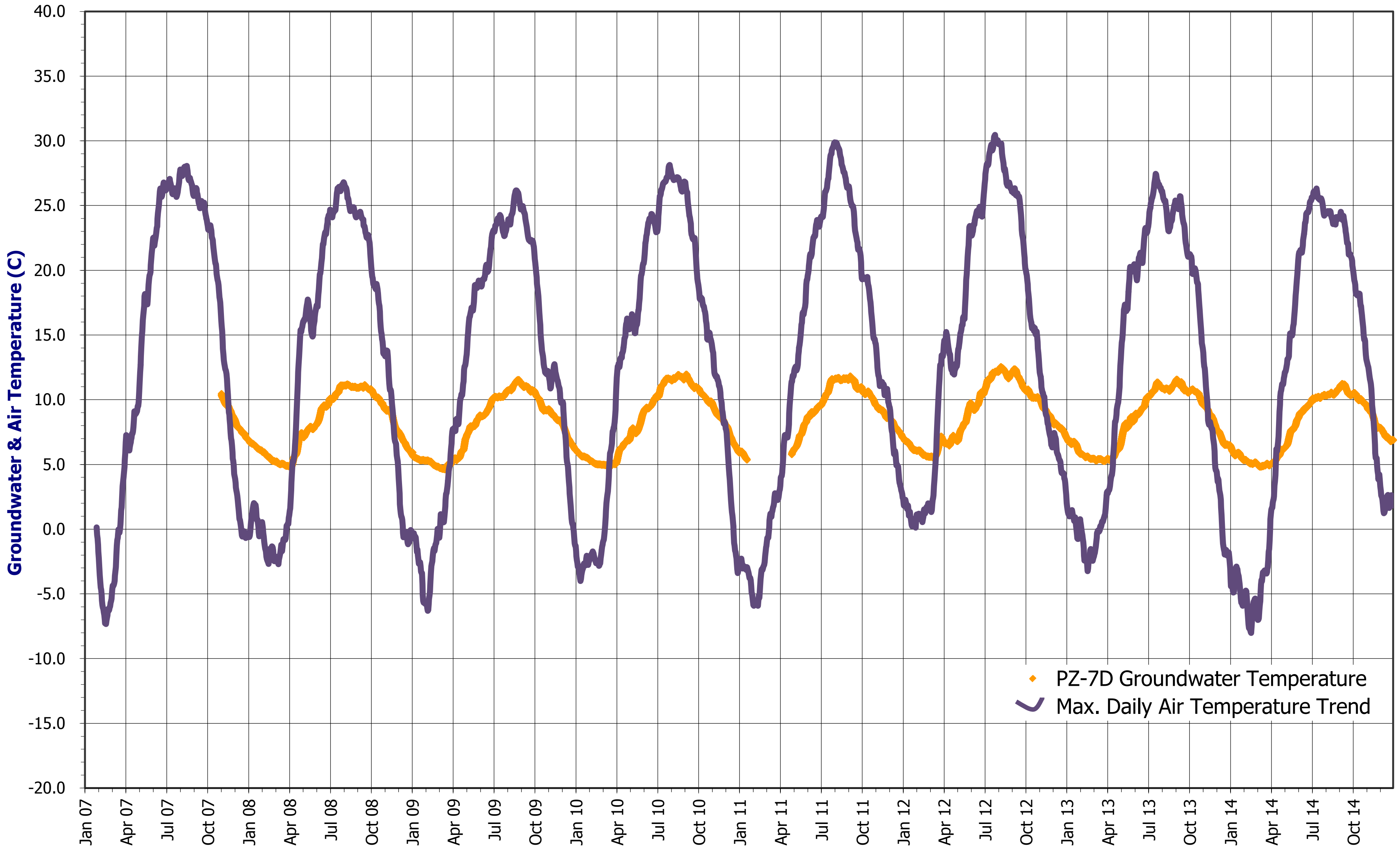
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph G 8**

Groundwater & Maximum Daily Air Temperature - PZ-7D (August 07 to December 14)



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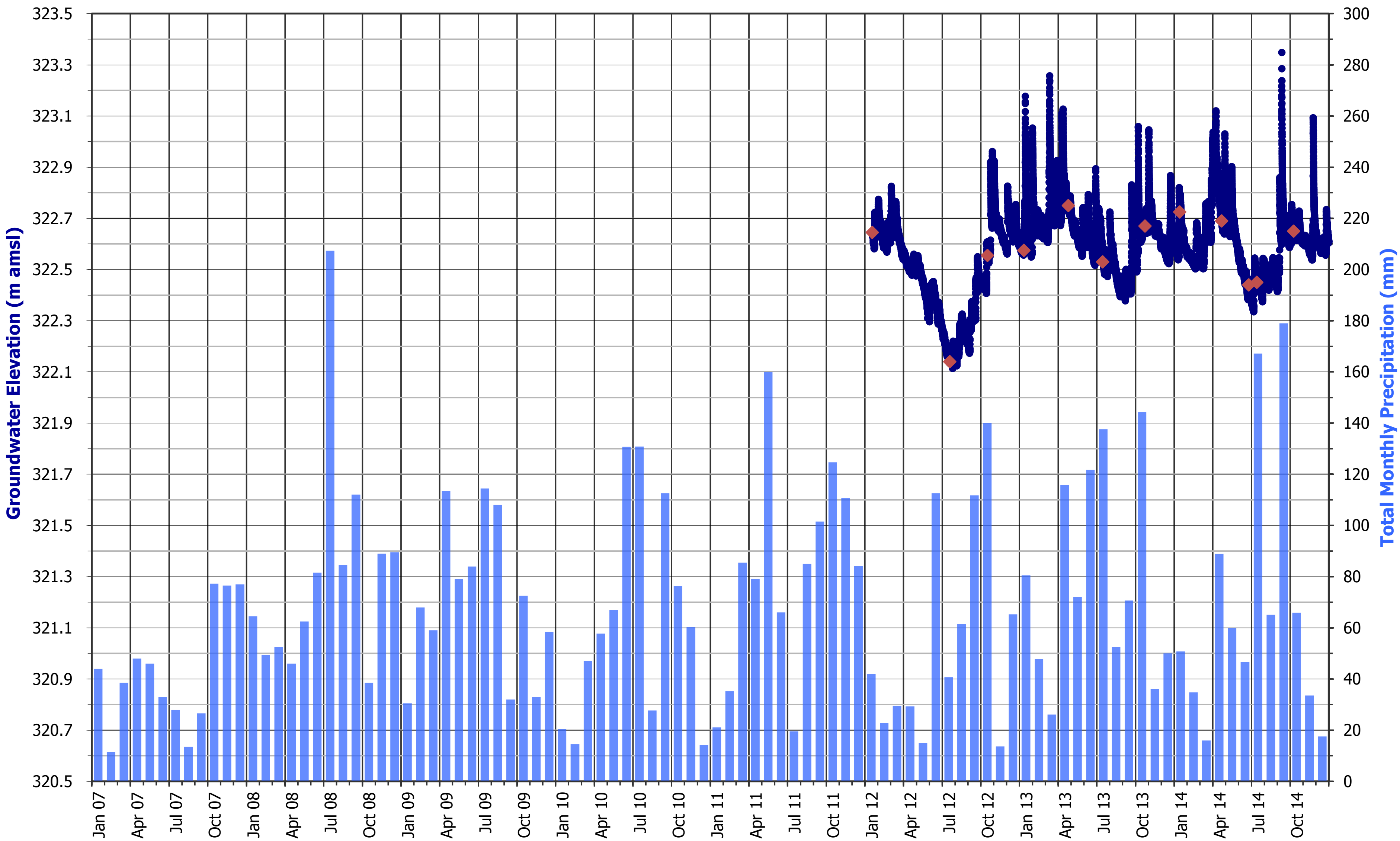
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph G 8a**

Groundwater Elevation & Precipitation - MW130A (January 12 to December 14)



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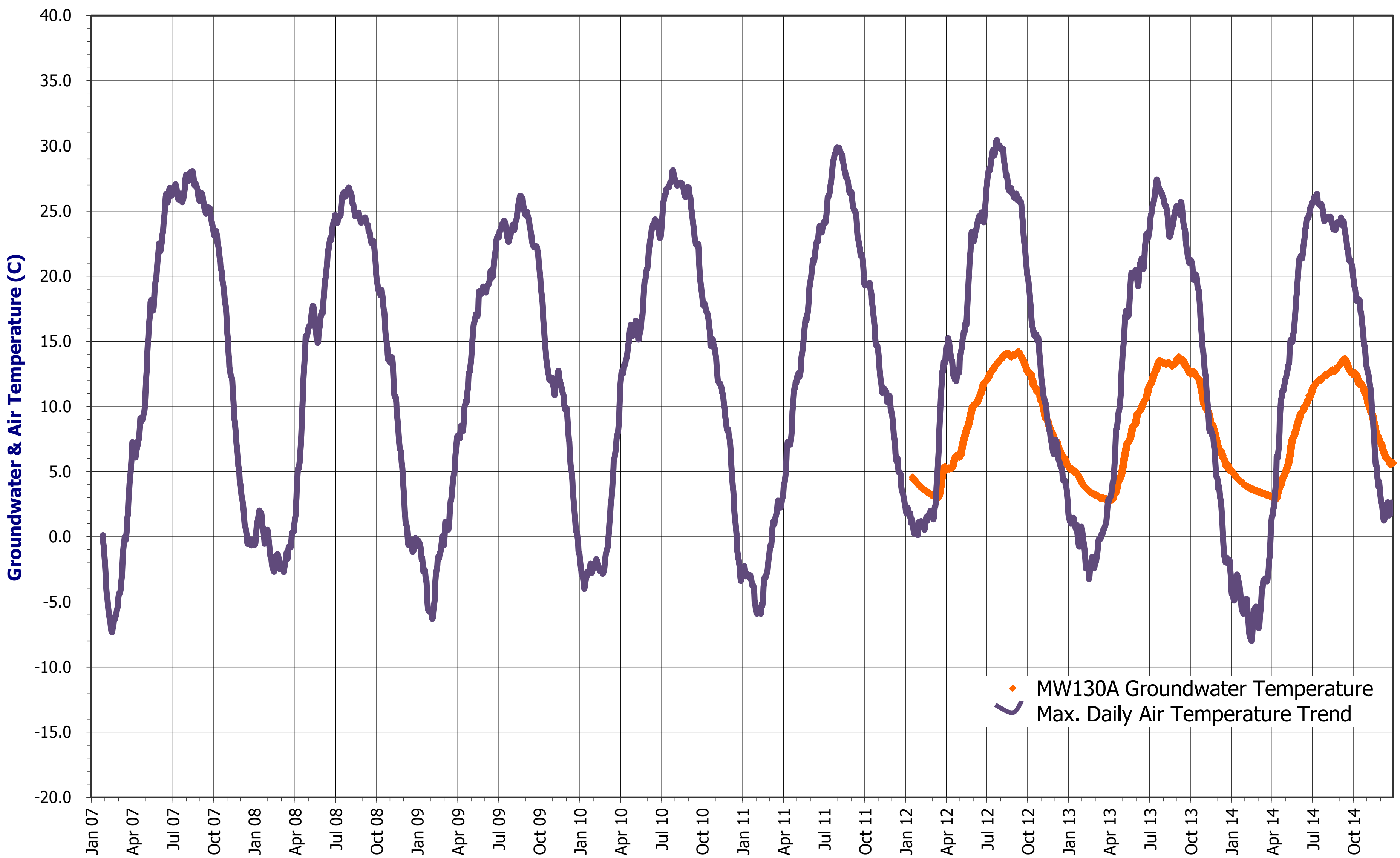
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph G 9**

Groundwater & Maximum Daily Air Temperature - MW130A (January 12 to December 14)



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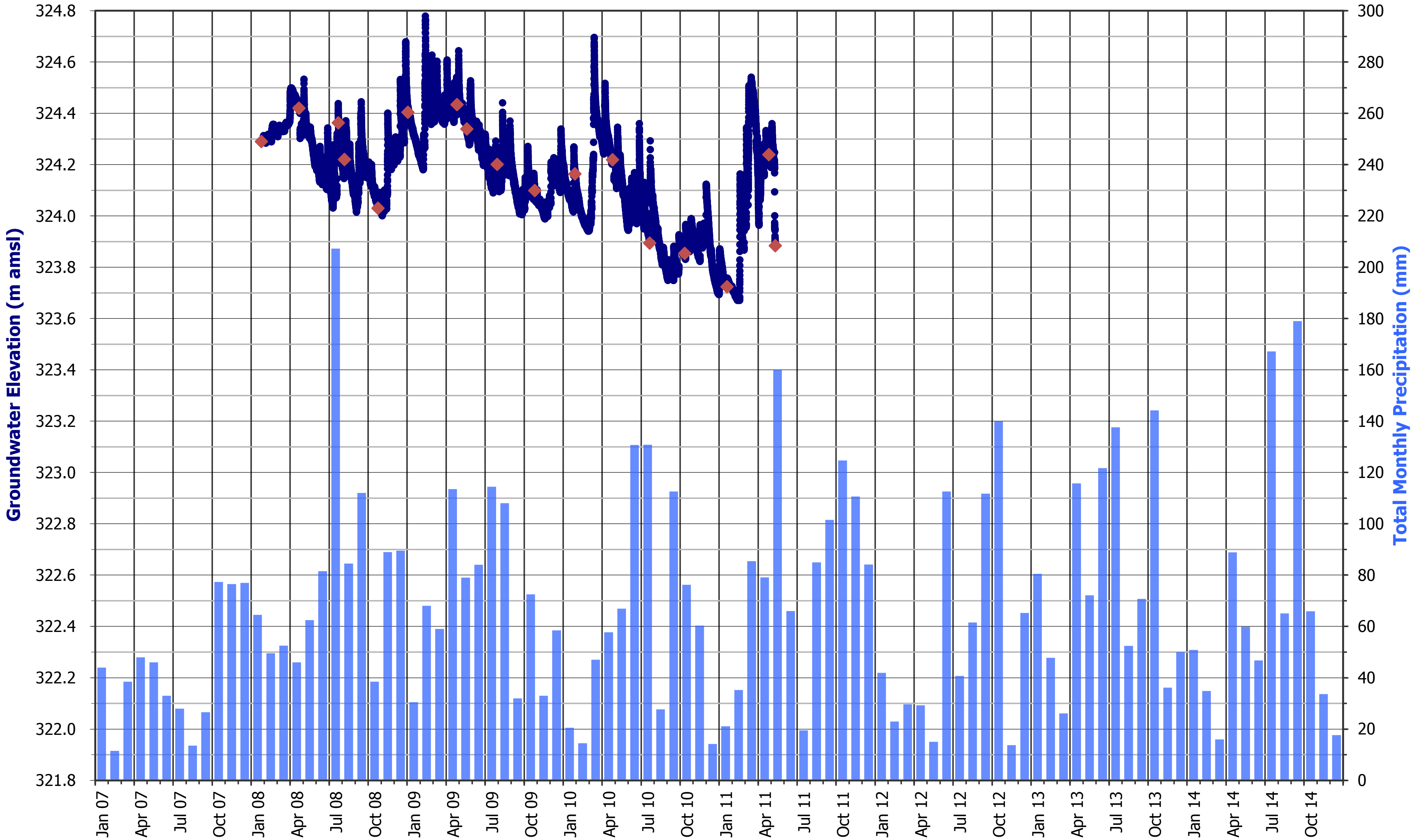
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014

Phase 1 - Core PSW Graph G 9a

Groundwater Elevation & Precipitation - MW001 (January 08 to May 11) Abandoned 2011



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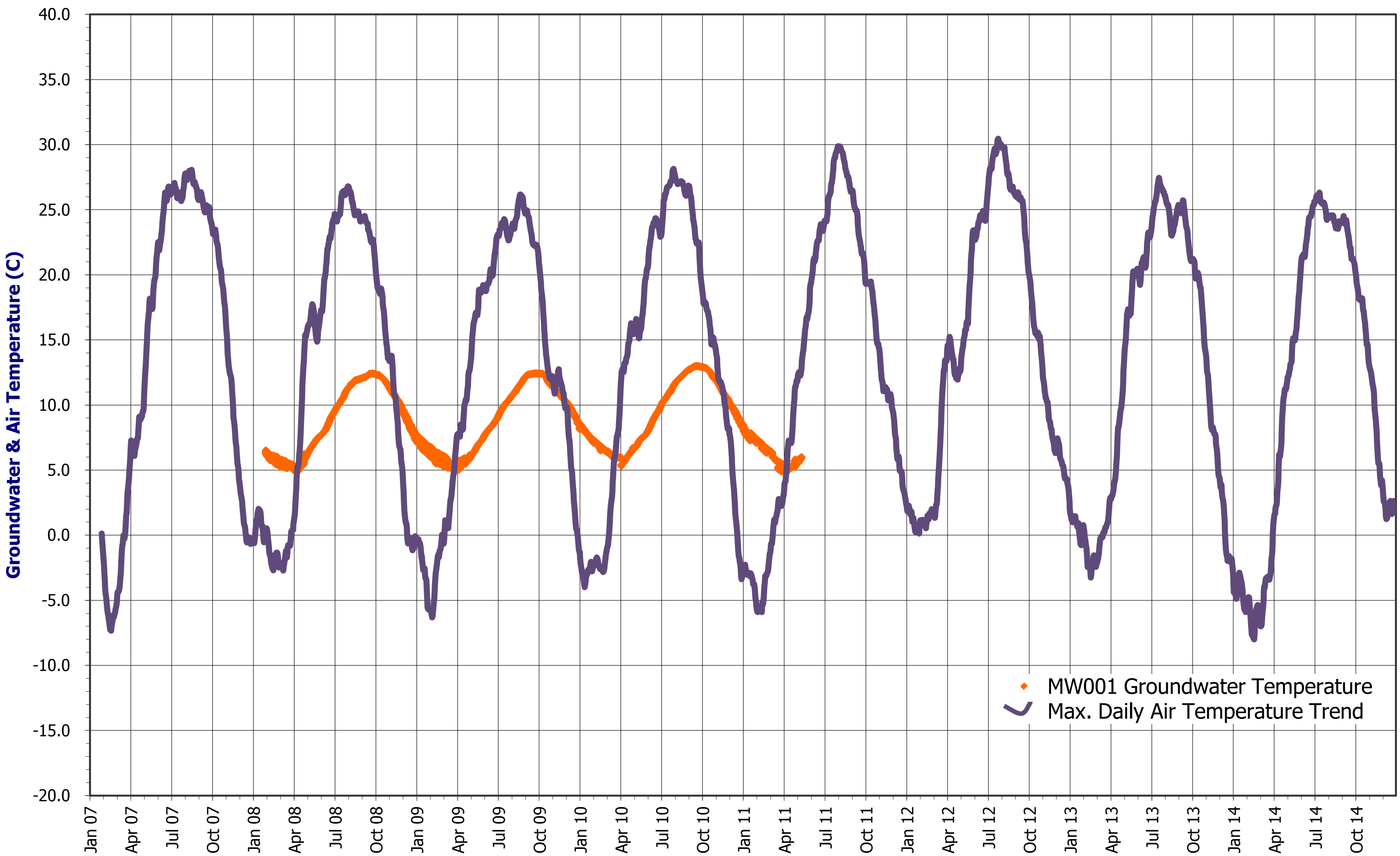
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph G 10**

Groundwater & Maximum Daily Air Temperature - MW001 (January 08 to May 11) Abandoned 2011



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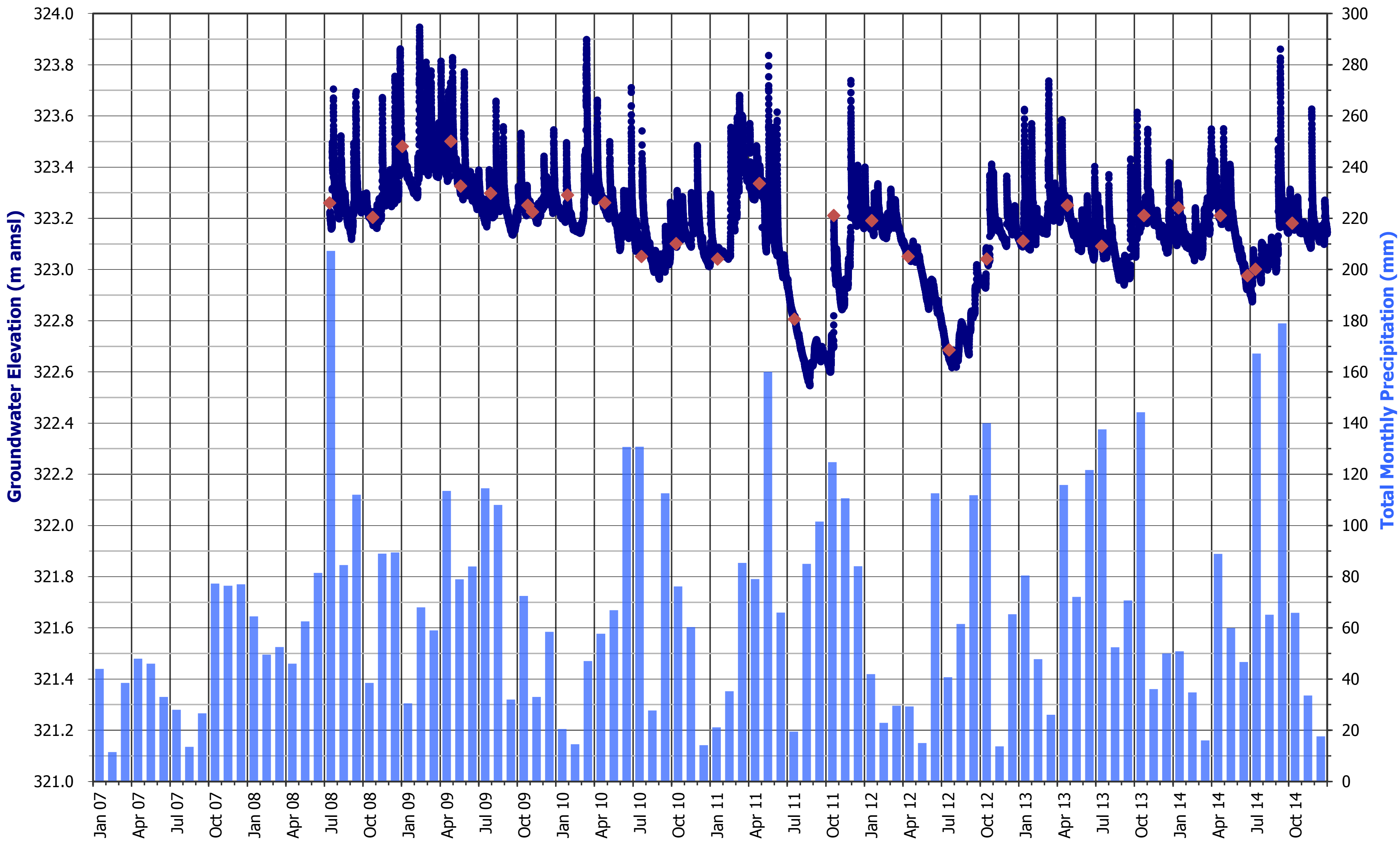
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2013 **Phase 1 - Core PSW** **Graph G 10a**

Groundwater Elevation & Precipitation - MW118A (July 08 to December 14)



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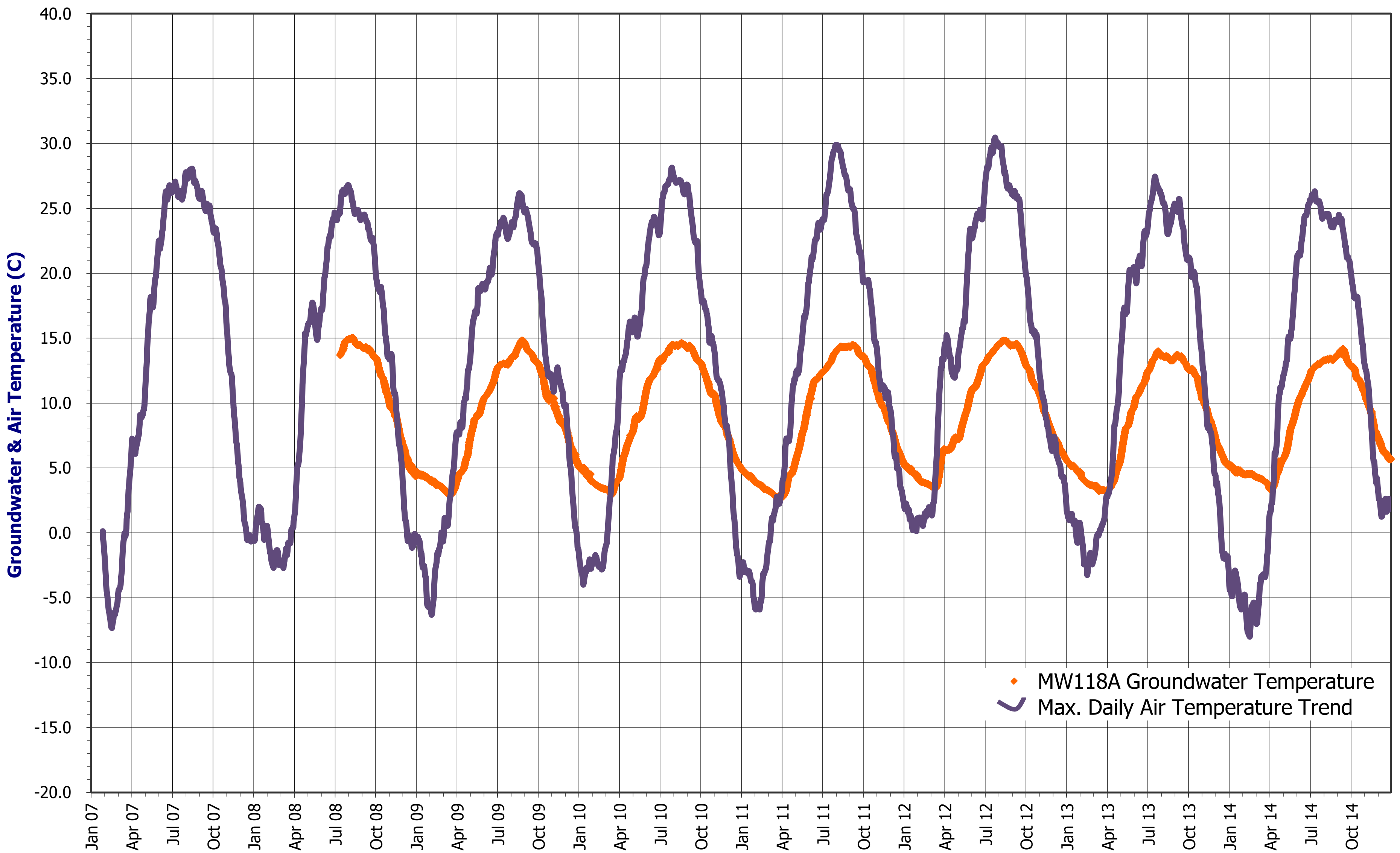
December 2014 **Phase 1 - Core PSW** **Graph G 11**

Groundwater & Maximum Daily Air Temperature - MW118A (July 08 to December 14)



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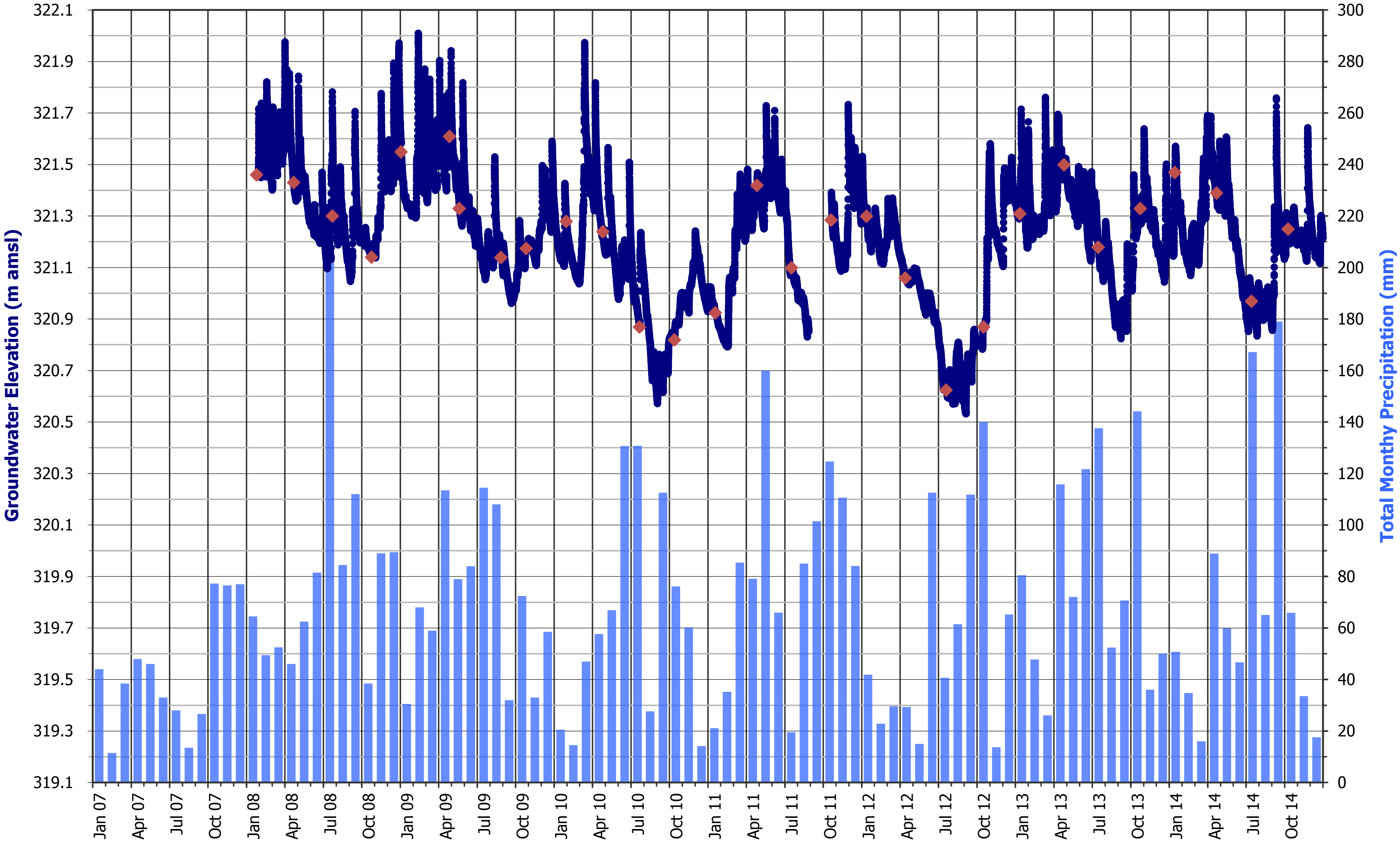
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph G 11a**

Groundwater Elevation & Precipitation - MW104 (January 08 to December 14)



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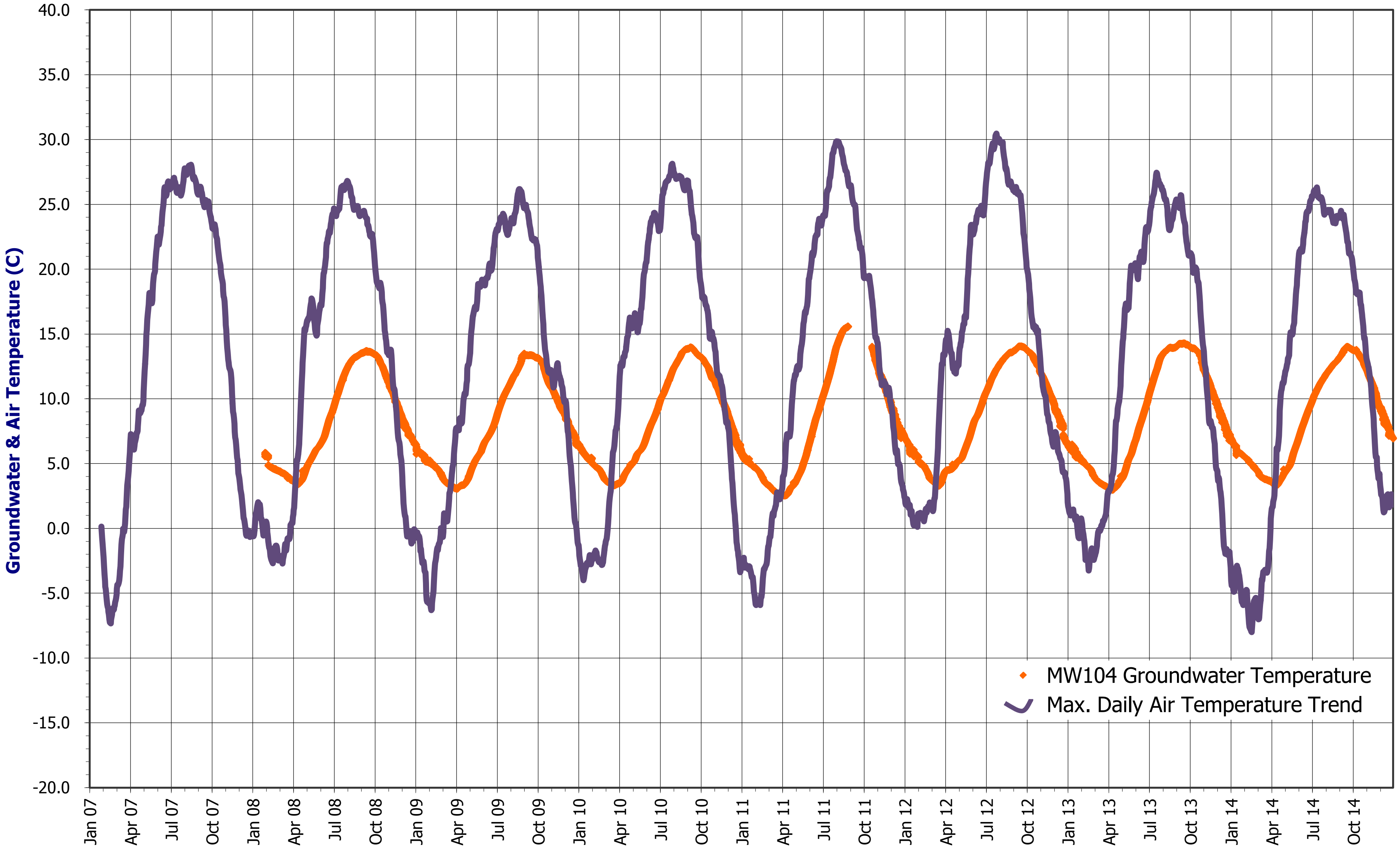
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014

Phase 1 - Core PSW Graph G 12

Groundwater & Maximum Daily Air Temperature - MW104 (January 08 to December 14)



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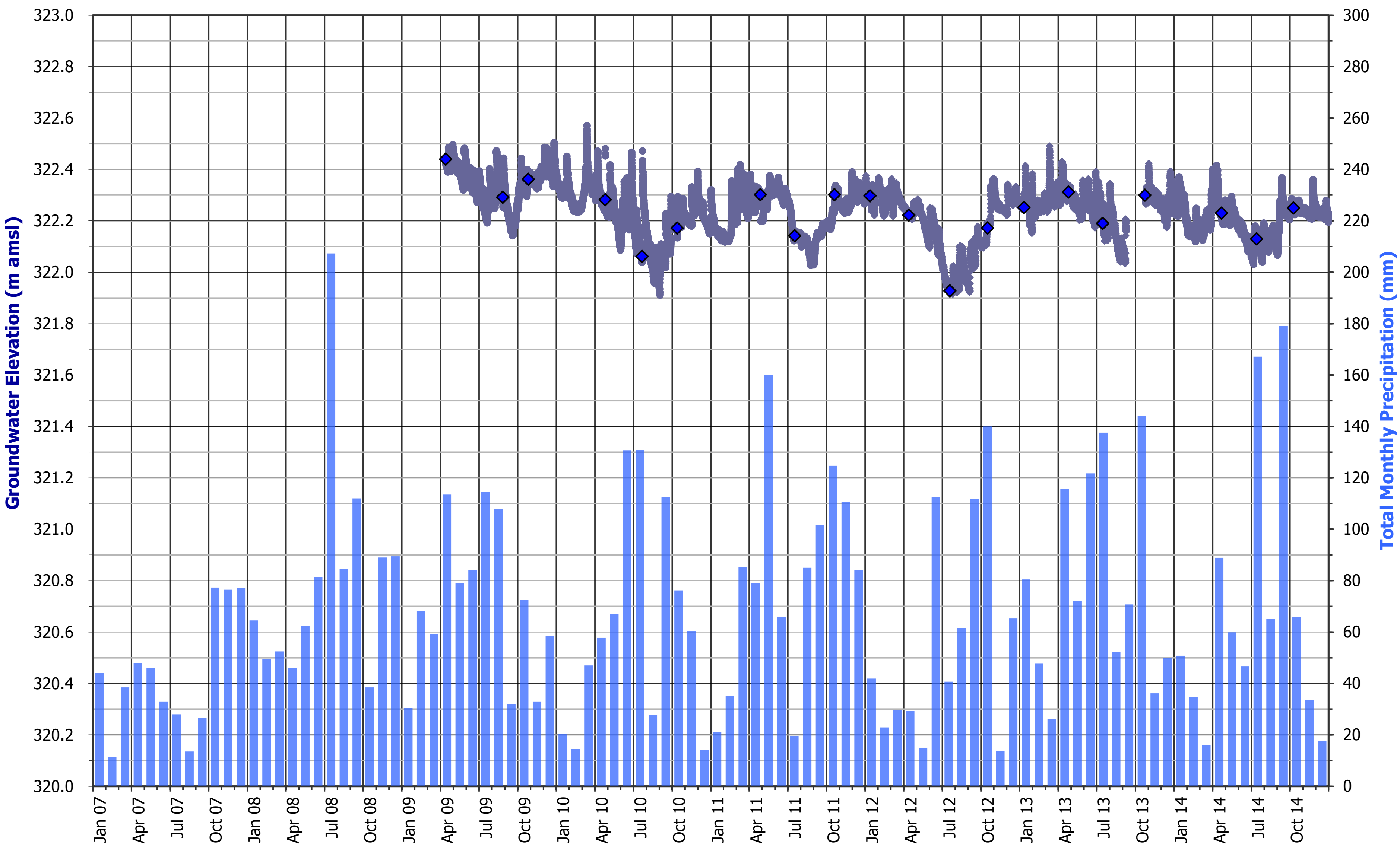
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph G 12a**

Groundwater Elevation & Precipitation - PZ-4D (April 09 to December 14)



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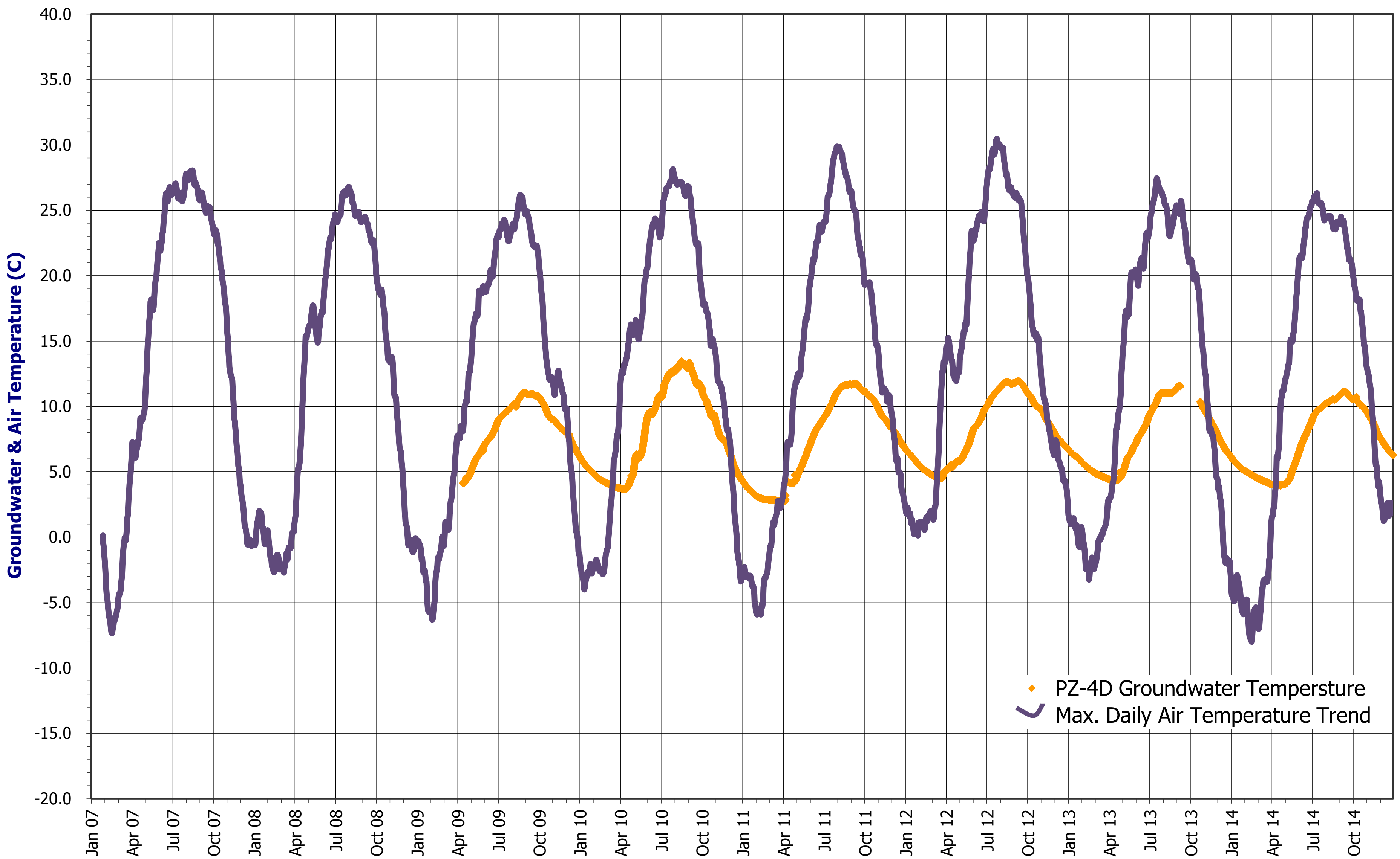
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph G 13**

Groundwater & Maximum Daily Air Temperature - PZ-4D (April 09 to December 14)



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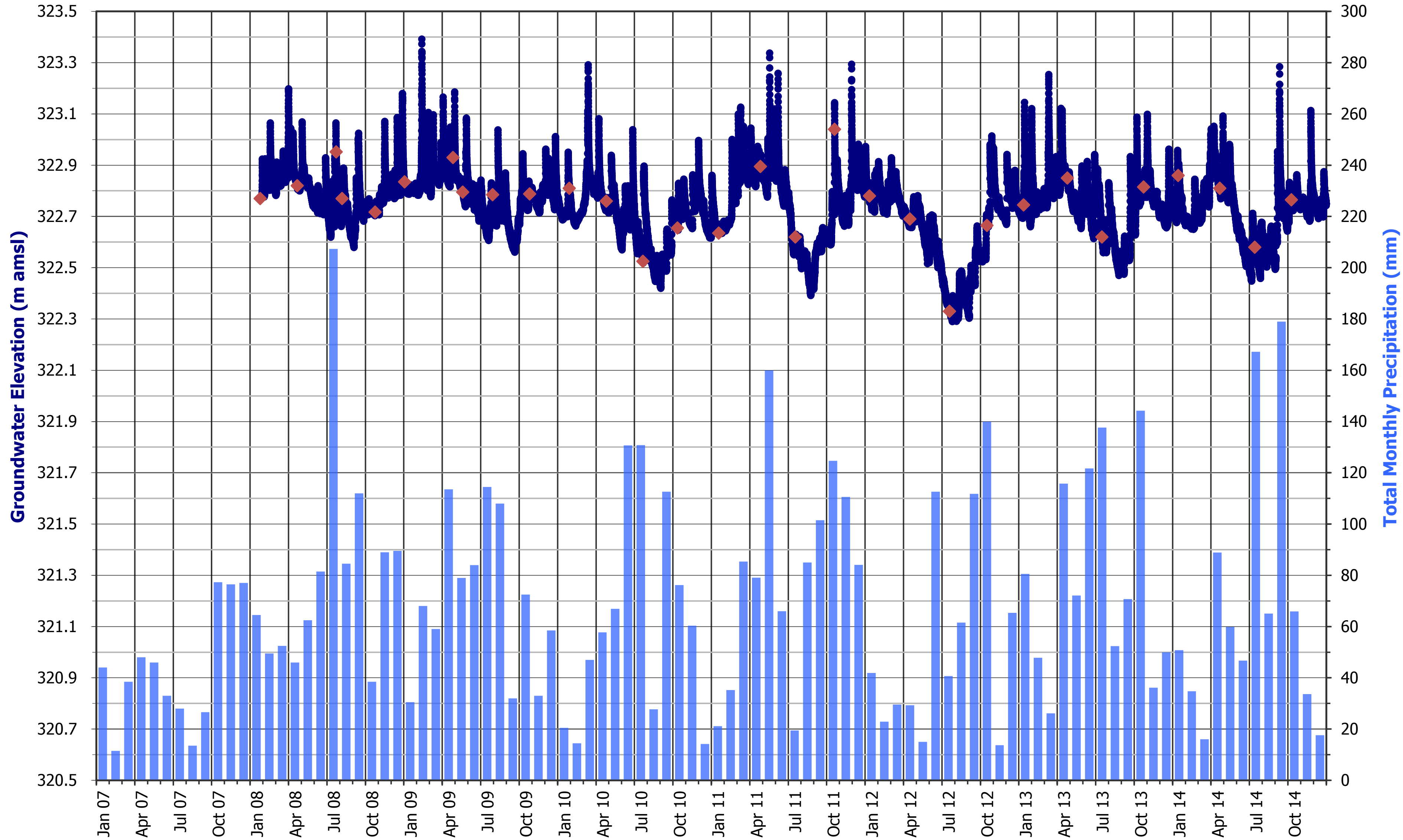
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph G 13a**

Groundwater Elevation & Precipitation - MW105 (January 08 to December 14)



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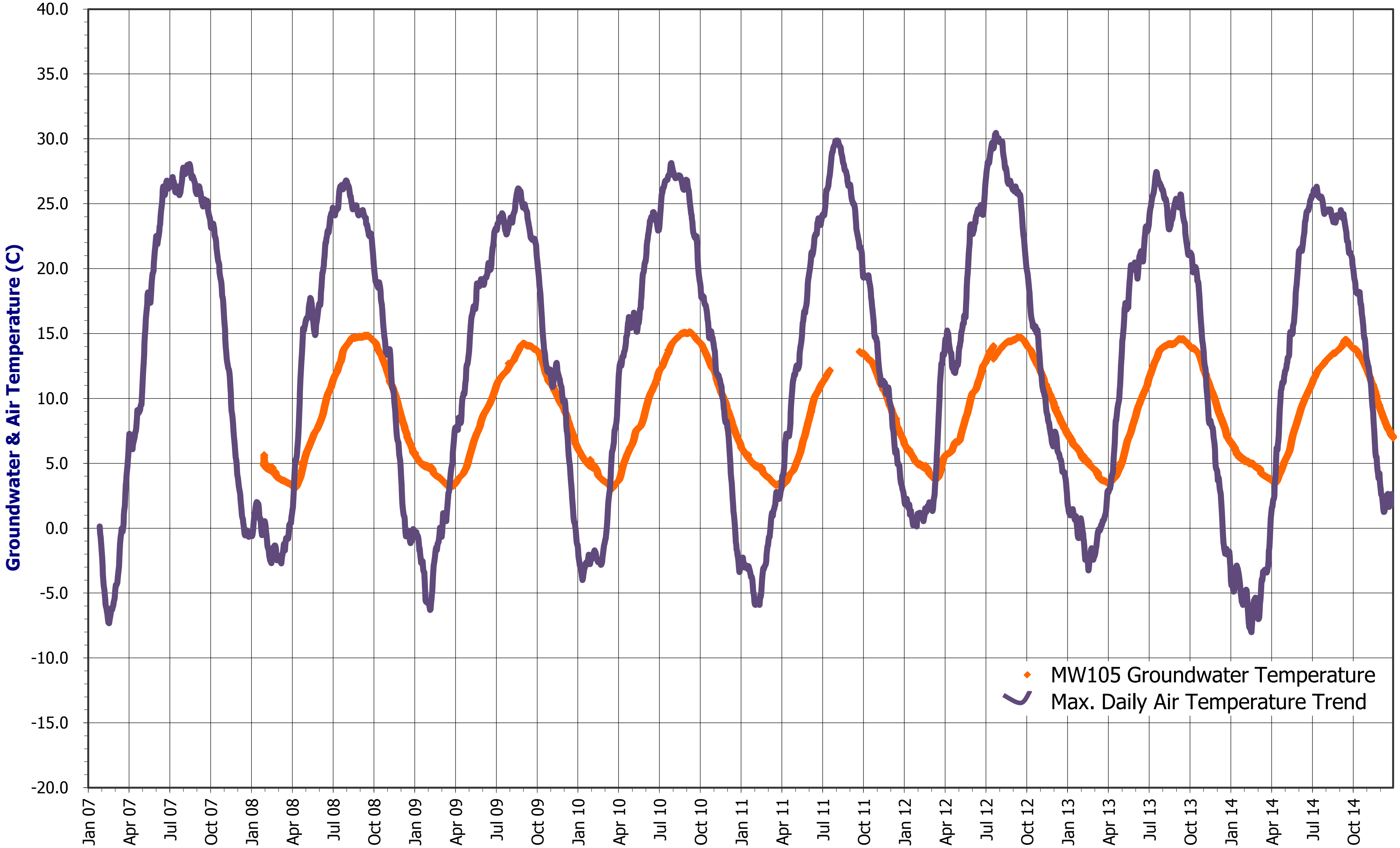
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph G 14**

Groundwater & Maximum Daily Air Temperature - MW105 (January 08 to December 14)



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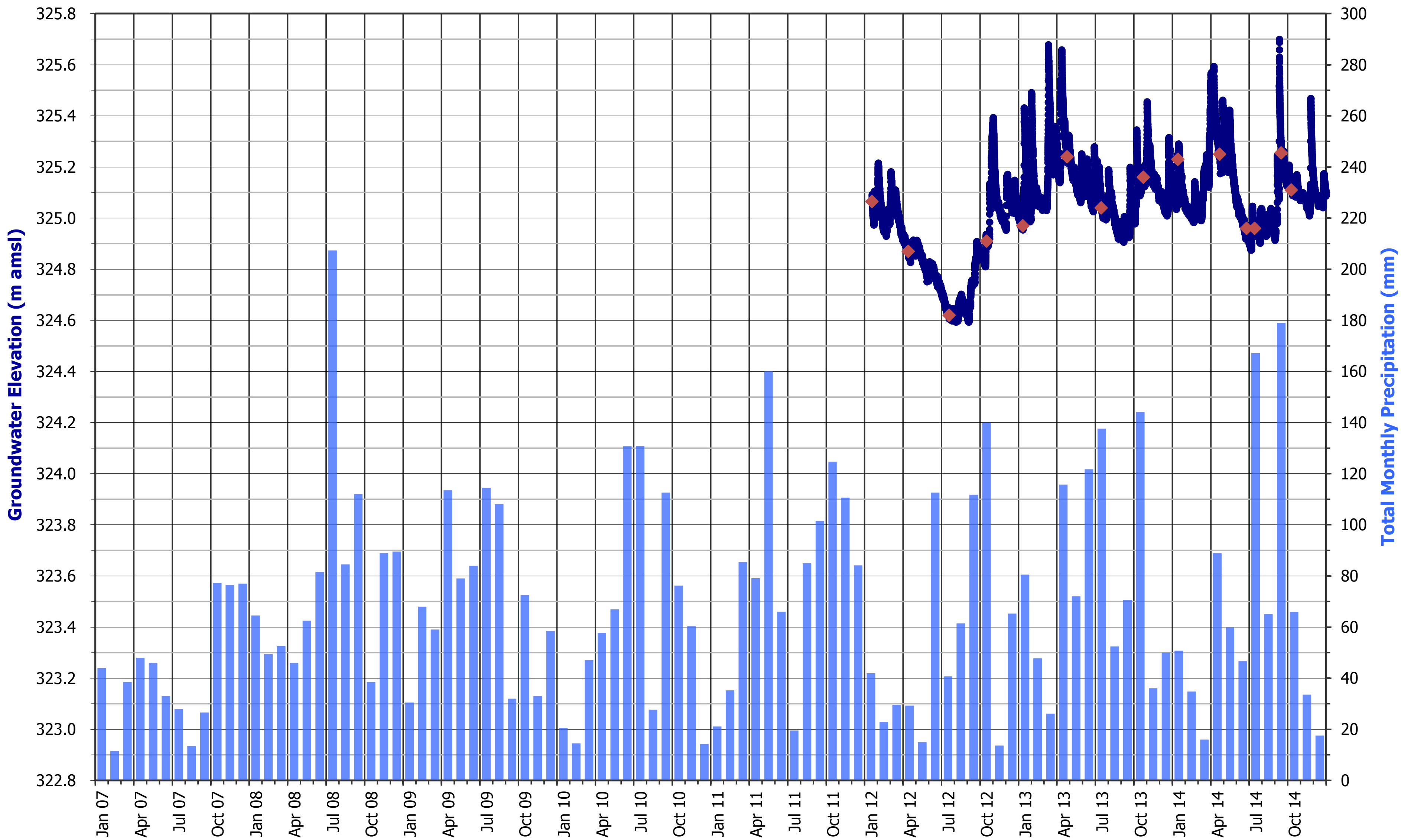
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph G 14a**

Groundwater Elevation & Precipitation - MW129 (January 12 to December 14)



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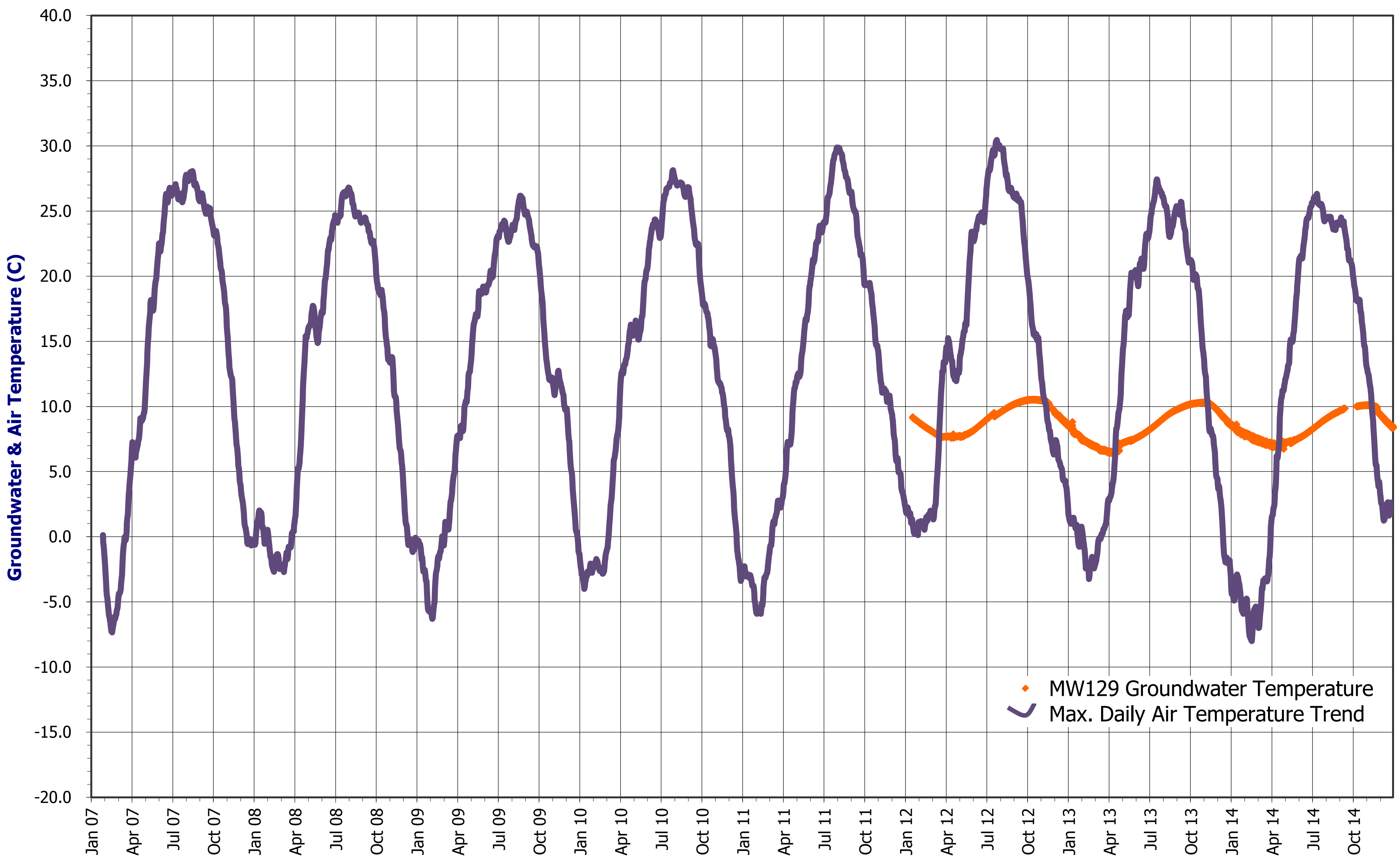
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph G 15**

Groundwater & Maximum Daily Air Temperature - MW129 (January 12 to December 14)



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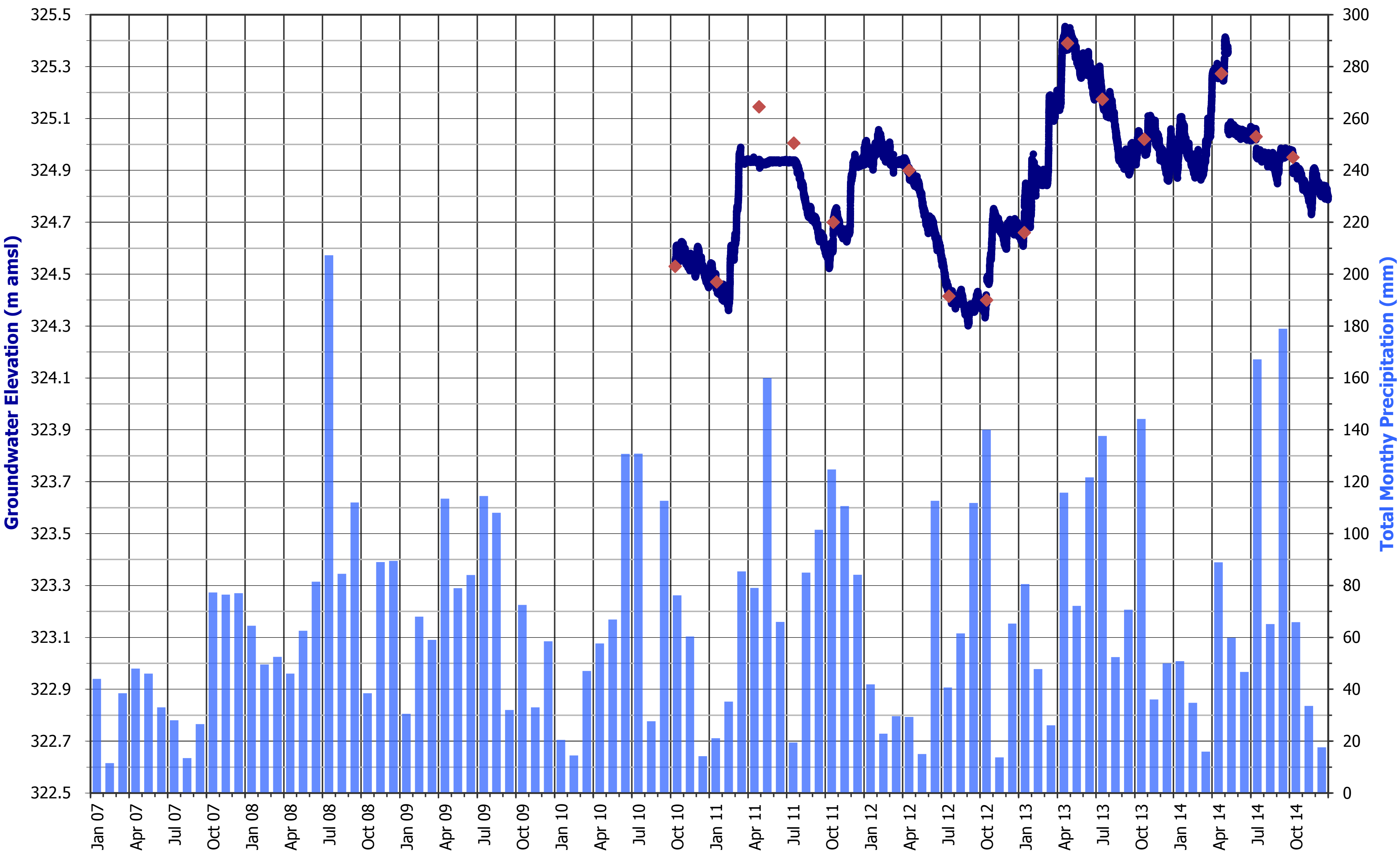
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph G 15a**

Groundwater Elevation & Precipitation - MW111 (October 10 to December 14)



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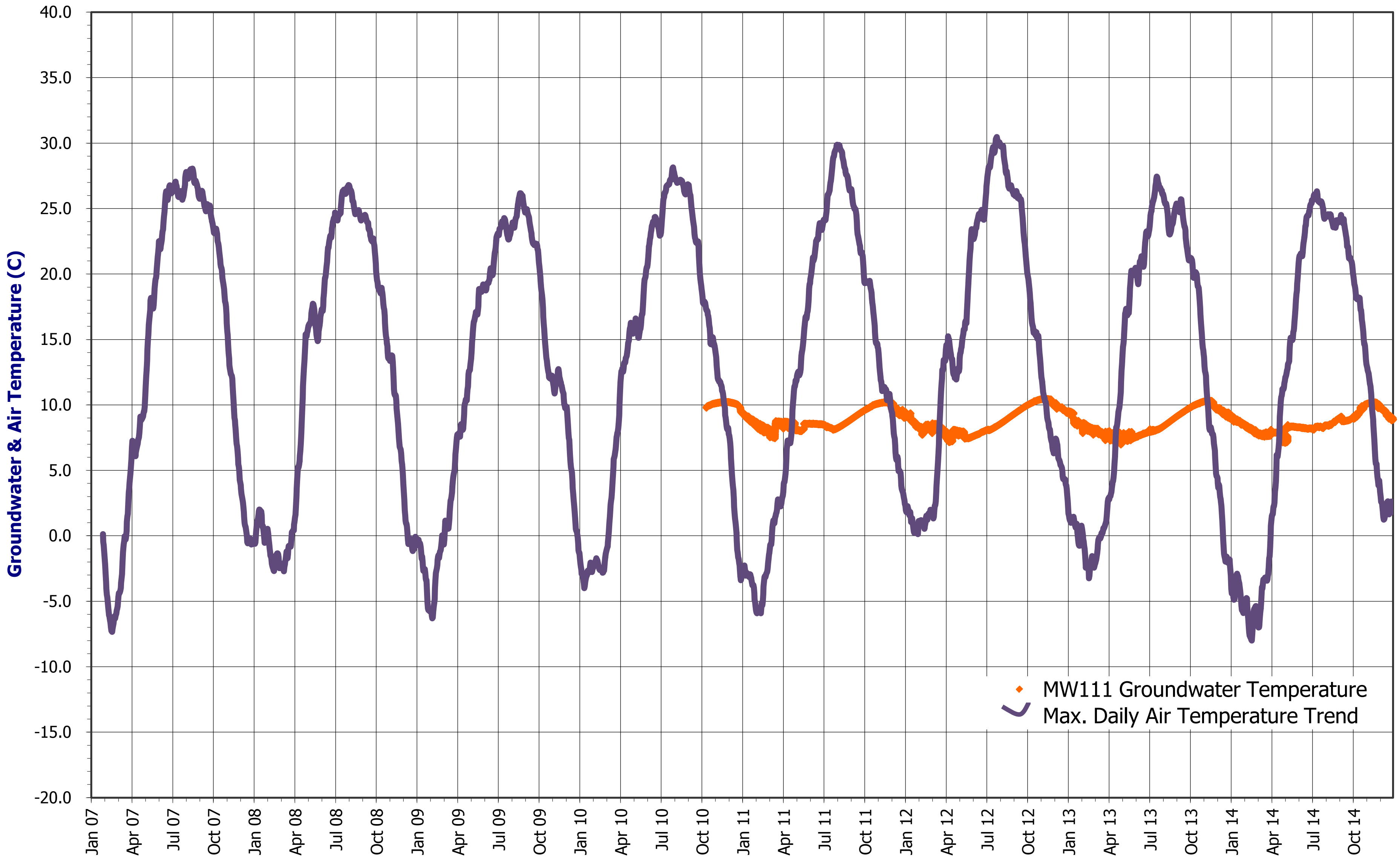
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph G 16**

Groundwater & Maximum Daily Air Temperature - MW111 (October 10 to December 14)



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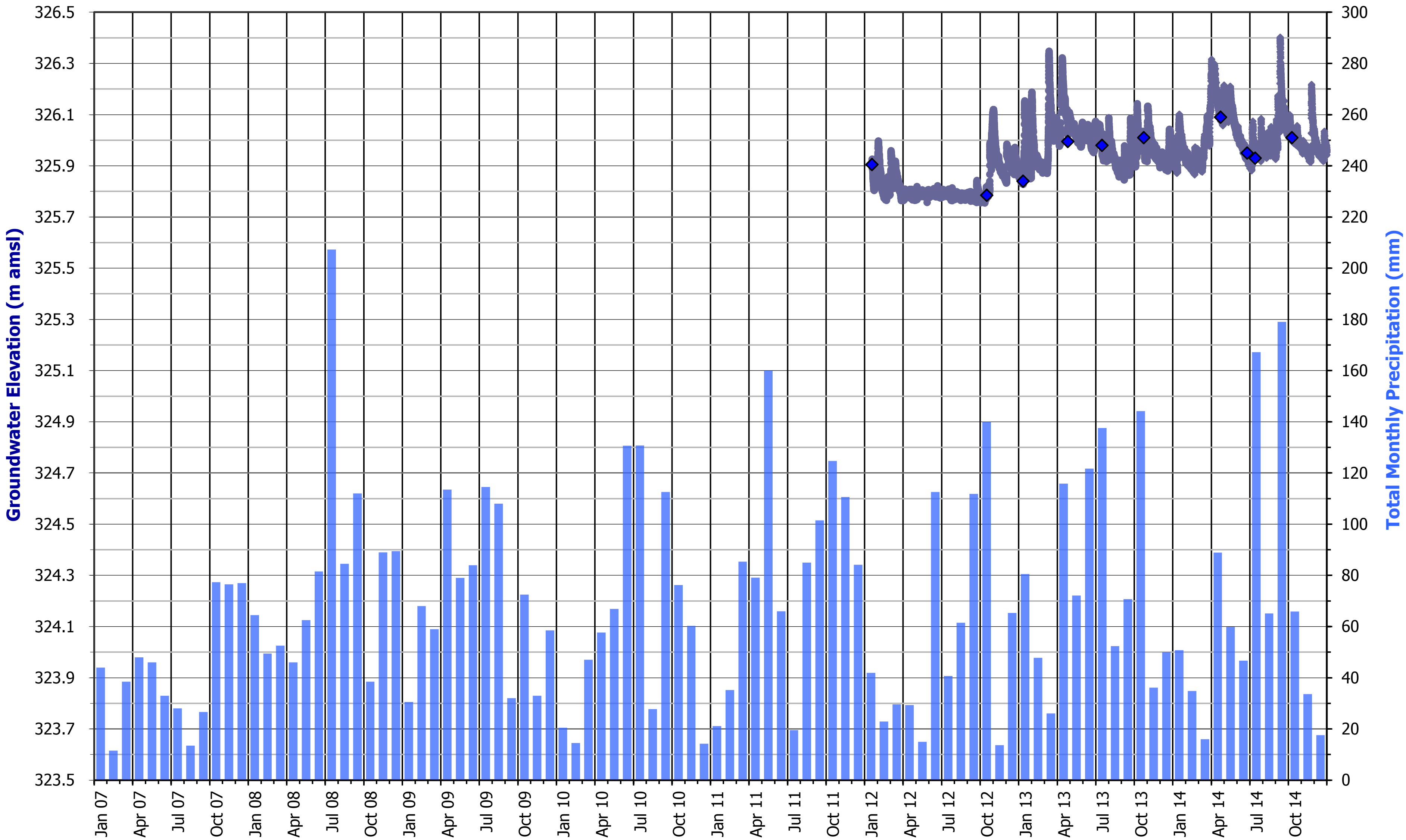
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Core PSW** **Graph G 16a**

Groundwater Elevation & Precipitation - PZ-12D (January 12 to December 14)



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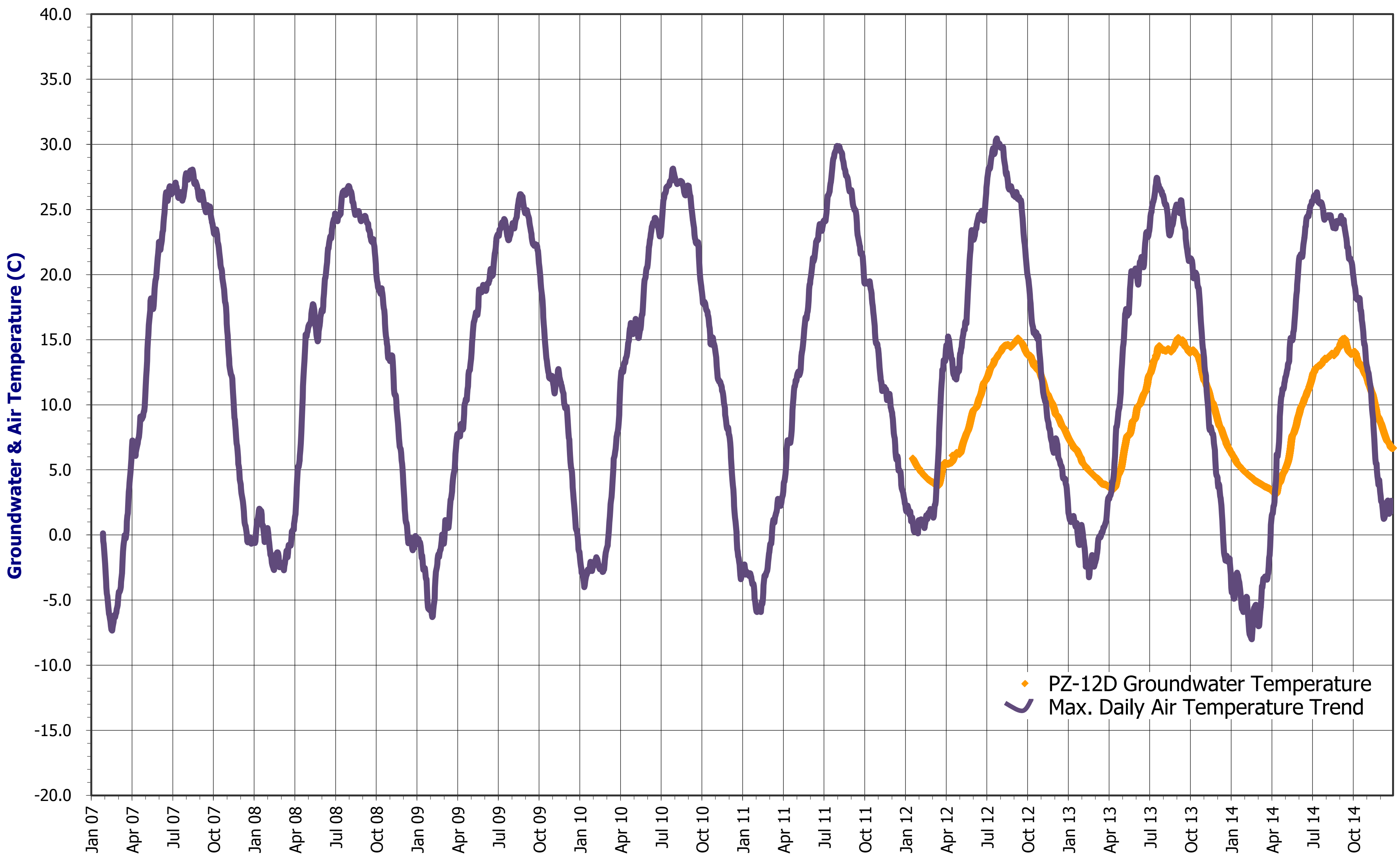
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Core PSW** **Graph G 17**

Groundwater & Maximum Daily Air Temperature - PZ-12D (January 12 to December 14)



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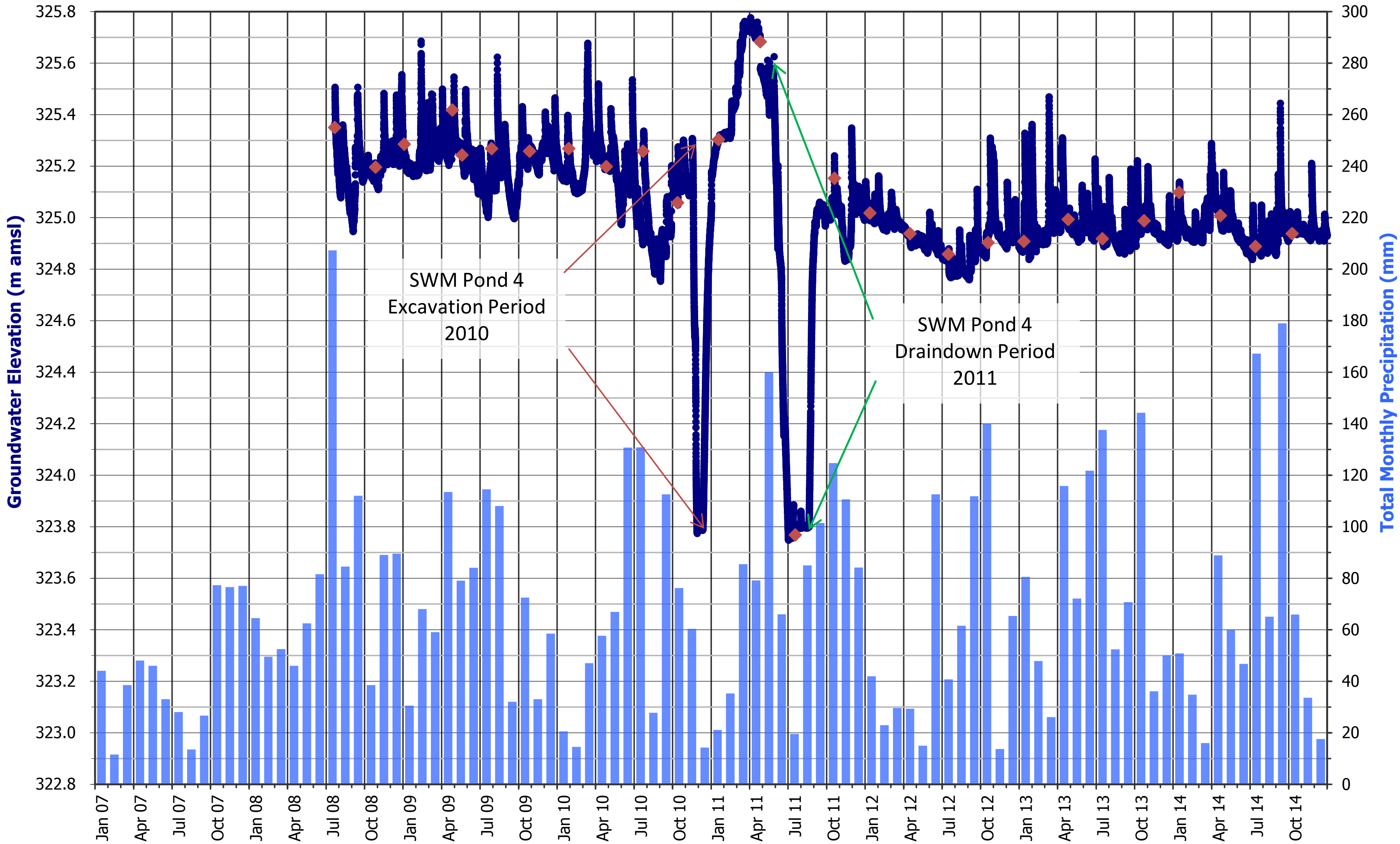
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Core PSW** **Graph G 17a**

Groundwater Elevation & Precipitation - MW119A (July 08 to December 14)



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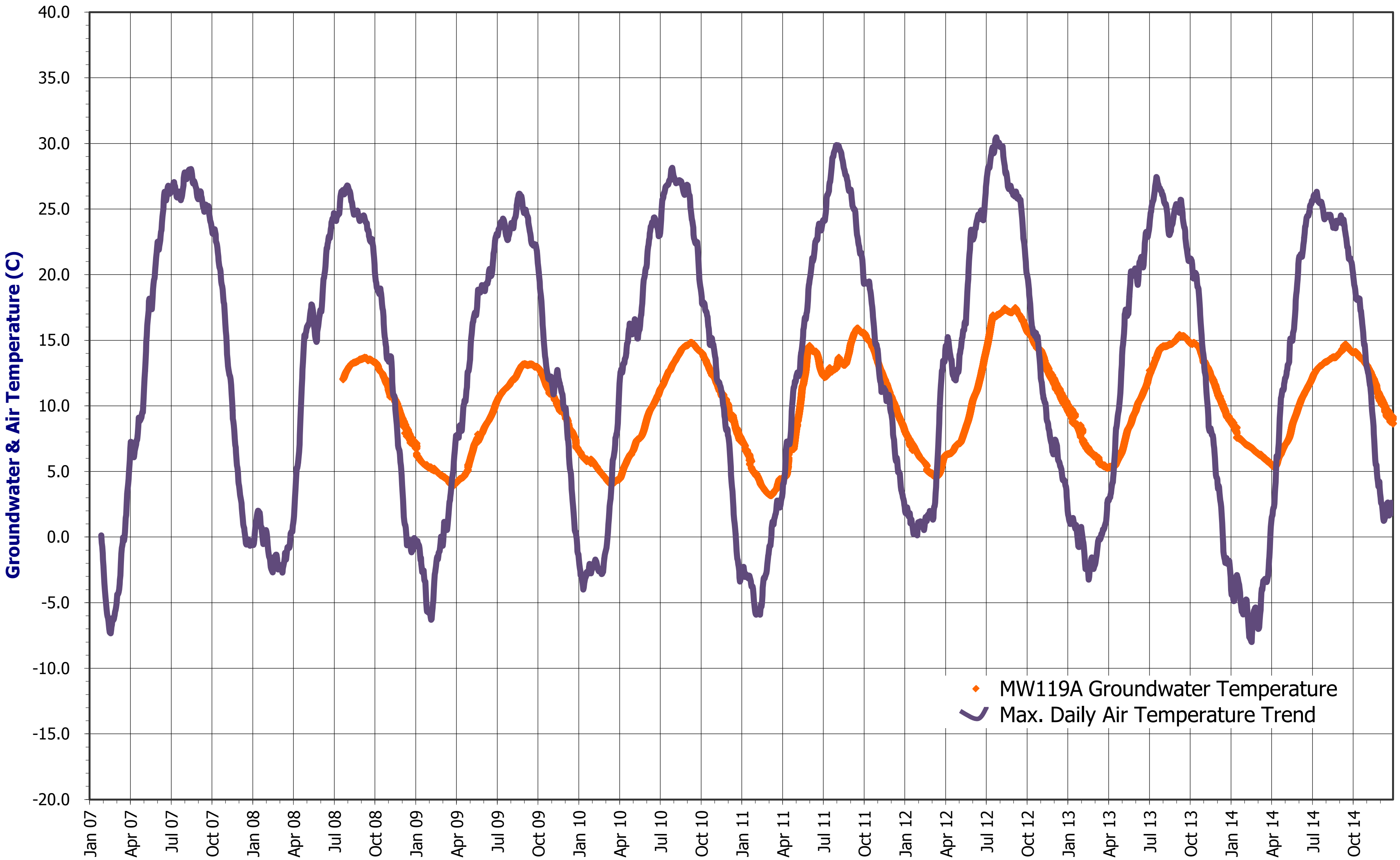
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Core PSW** **Graph G 18**

Groundwater & Maximum Daily Air Temperature - MW119A (July 08 to December 14)



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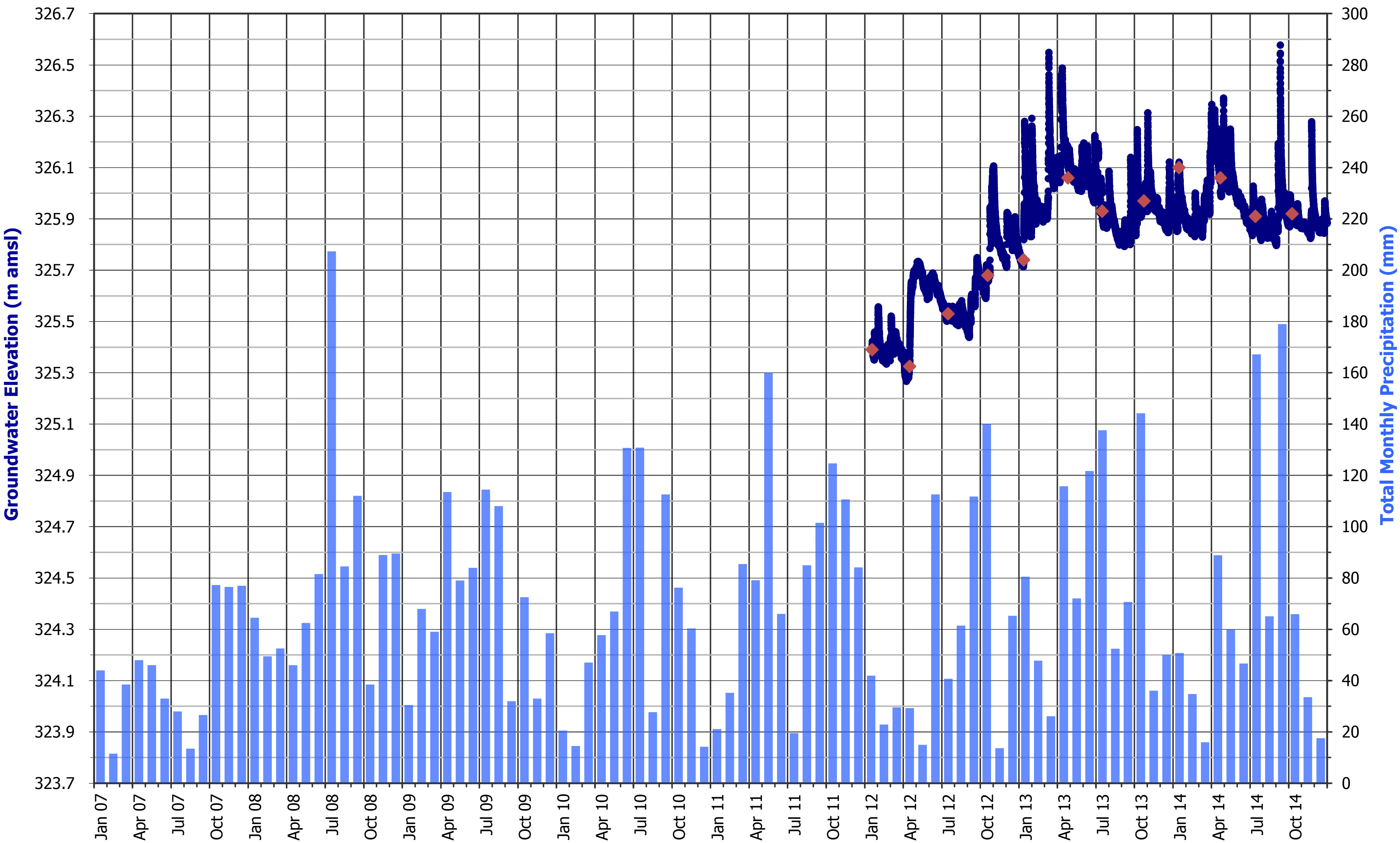
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Core PSW** **Graph G 18a**

Groundwater Elevation & Precipitation - MW131 (January 12 to December 14)



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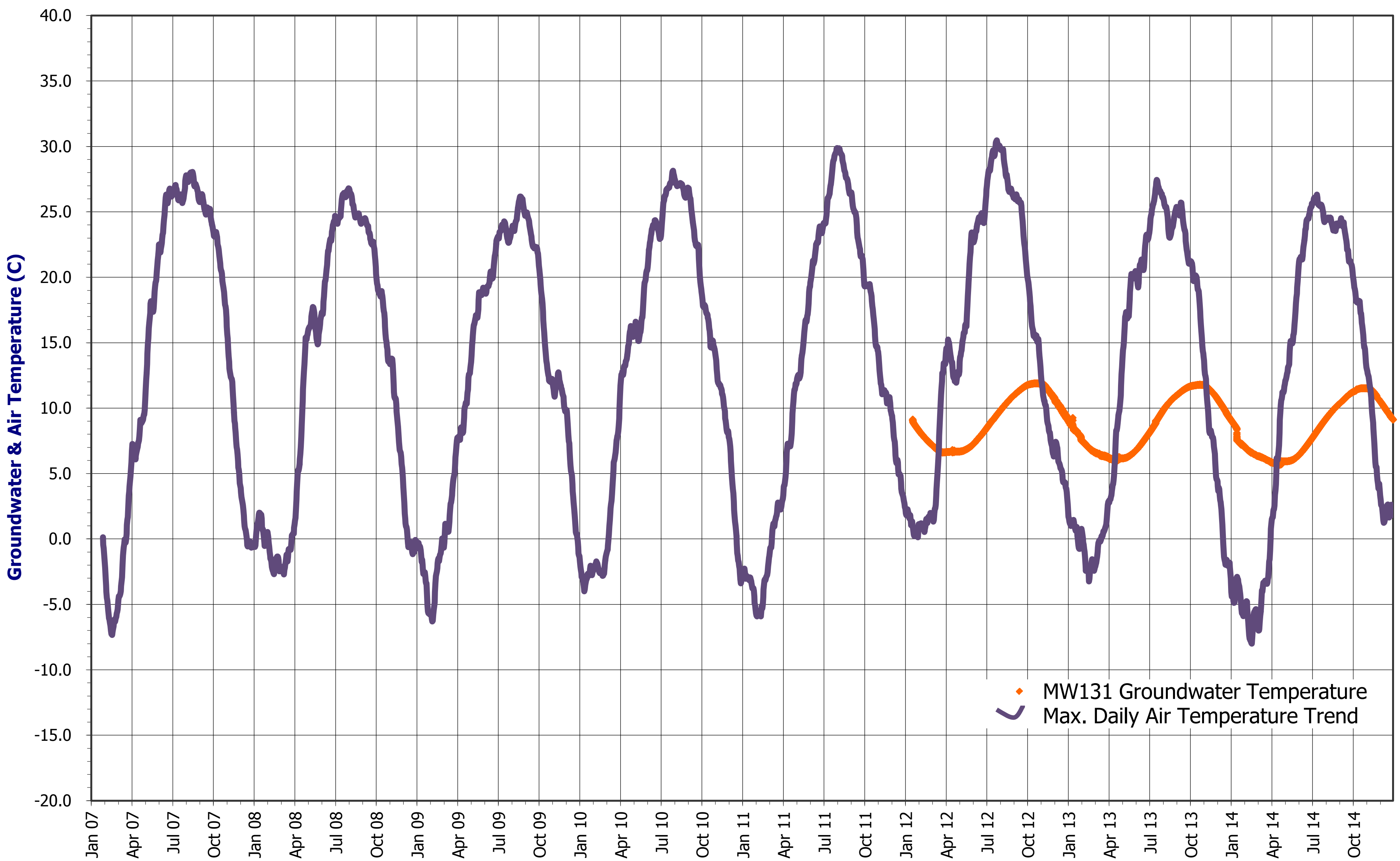
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Core PSW** **Graph G 19**

Groundwater & Maximum Daily Air Temperature - MW131 (January 12 to December 14)



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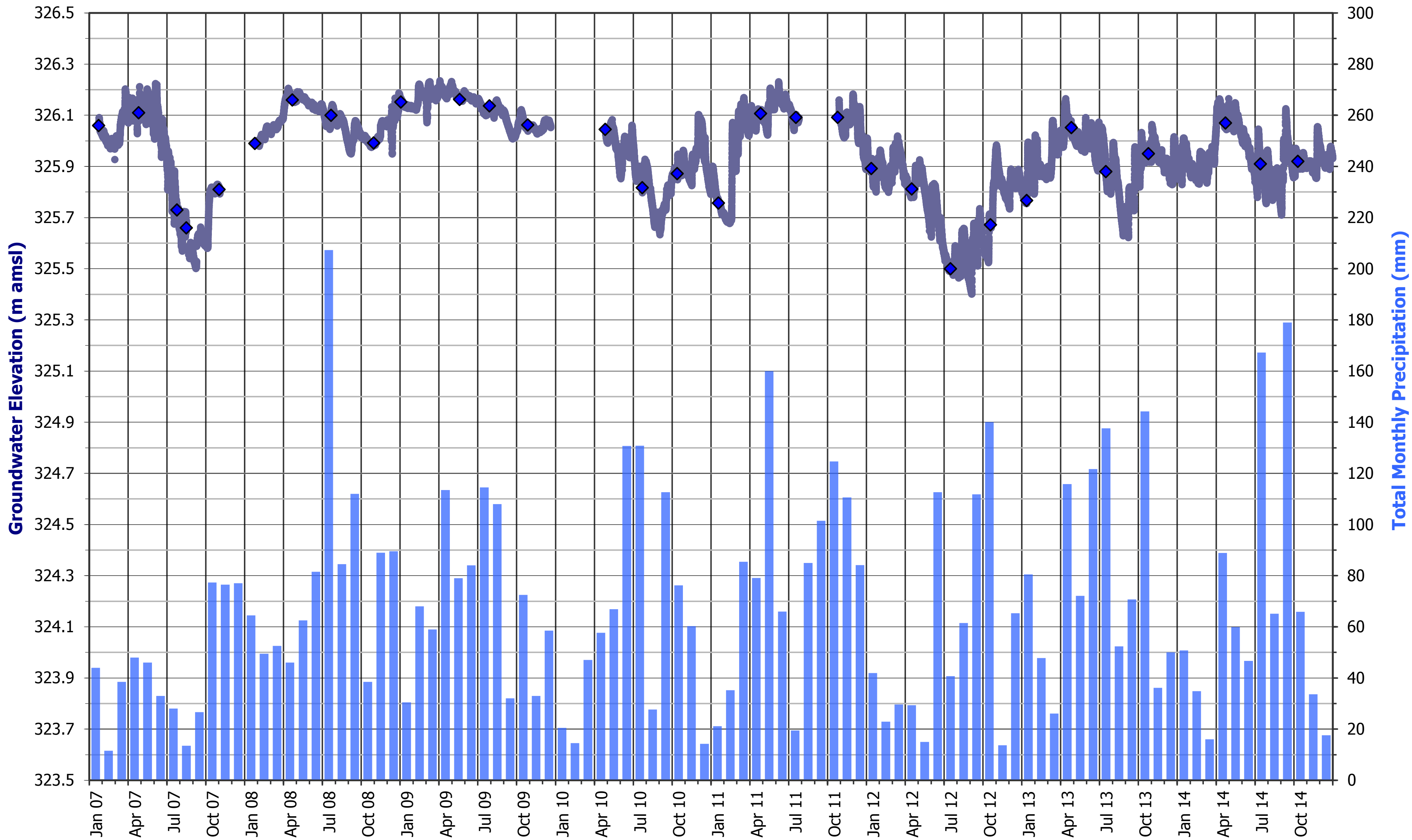
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Core PSW** **Graph G 19a**

Groundwater Elevation & Precipitation - PZ-2D (January 07 to December 14)



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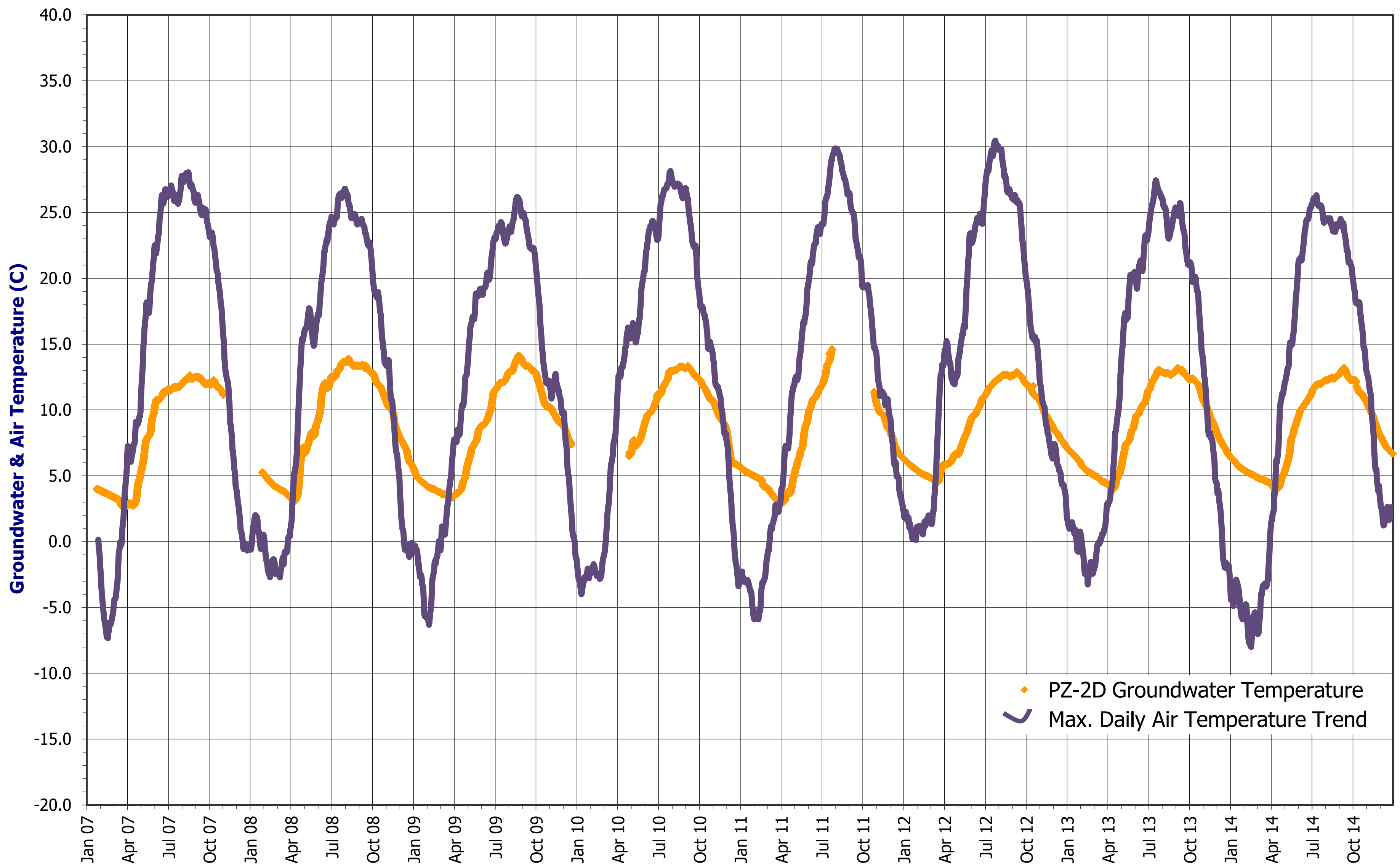
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phases 2 & 3 - Core PSW** **Graph G 20**

Groundwater & Maximum Daily Air Temperature - PZ-2D (March 07 to December 14)



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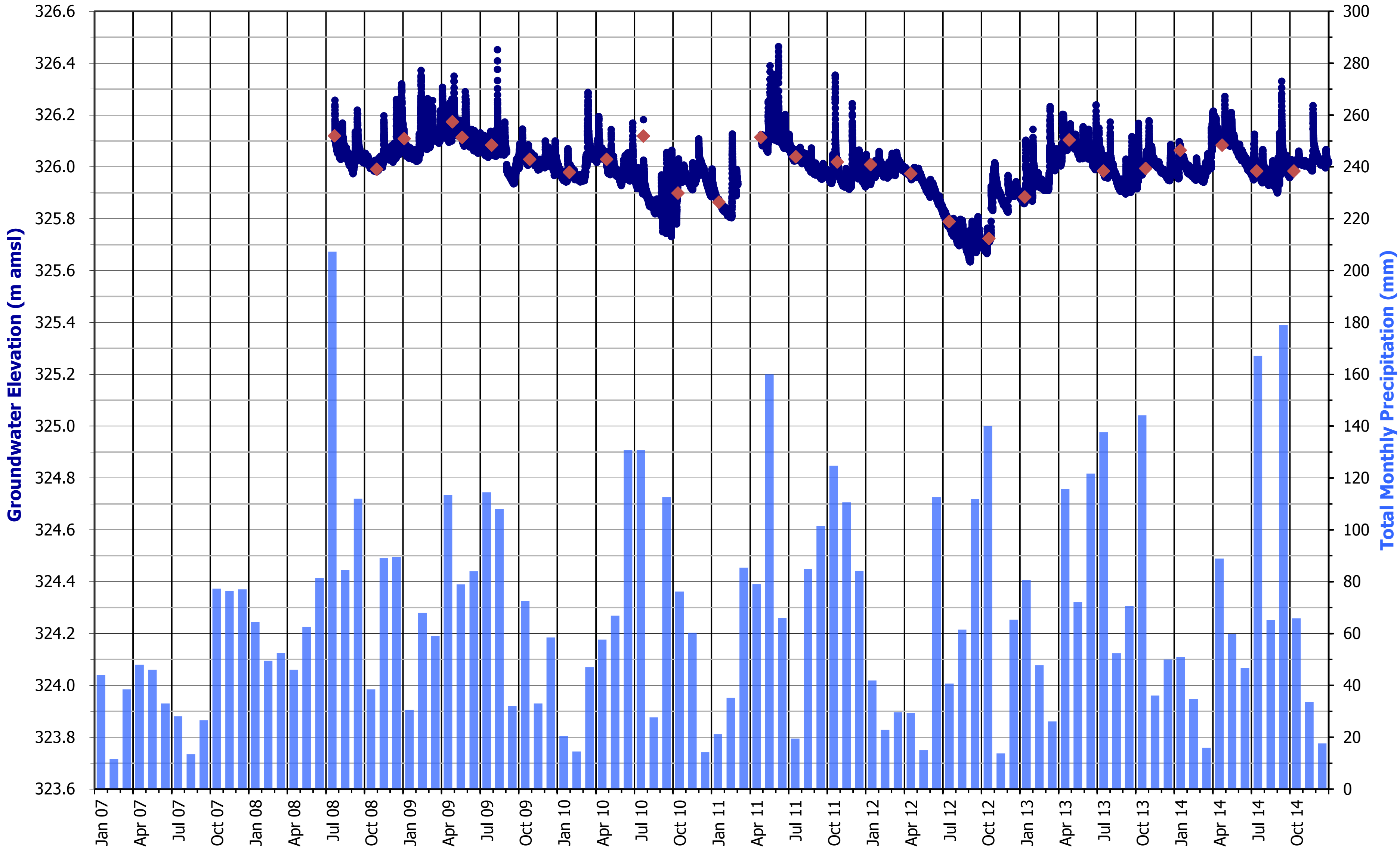
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phases 2 & 3 - Core PSW** **Graph G 20a**

Groundwater Elevation & Precipitation - MW122A (July 08 to December 14)



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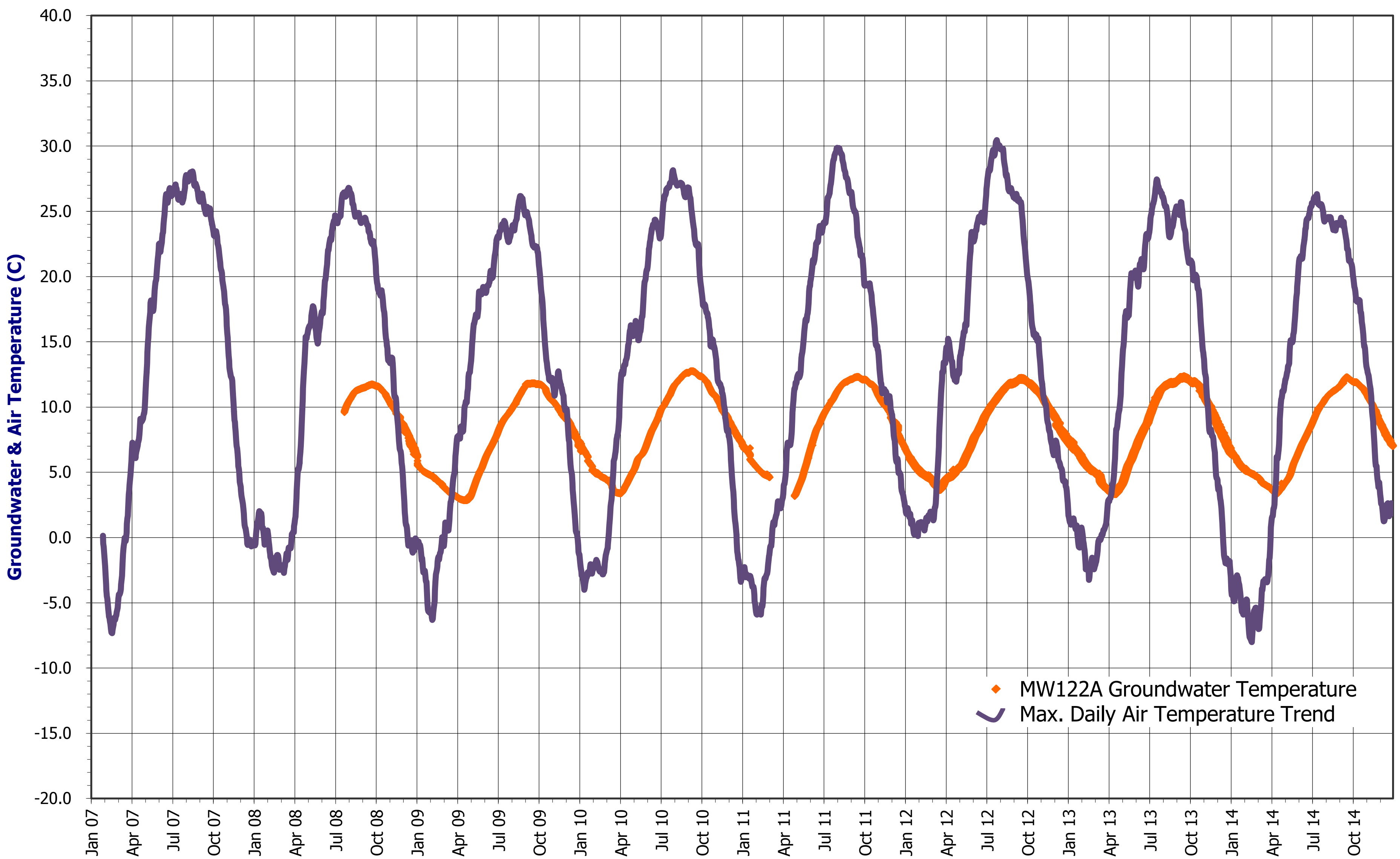
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 3 - Core PSW** **Graph G 21**

Groundwater & Maximum Daily Air Temperature - MW122A (July 08 to December 14)



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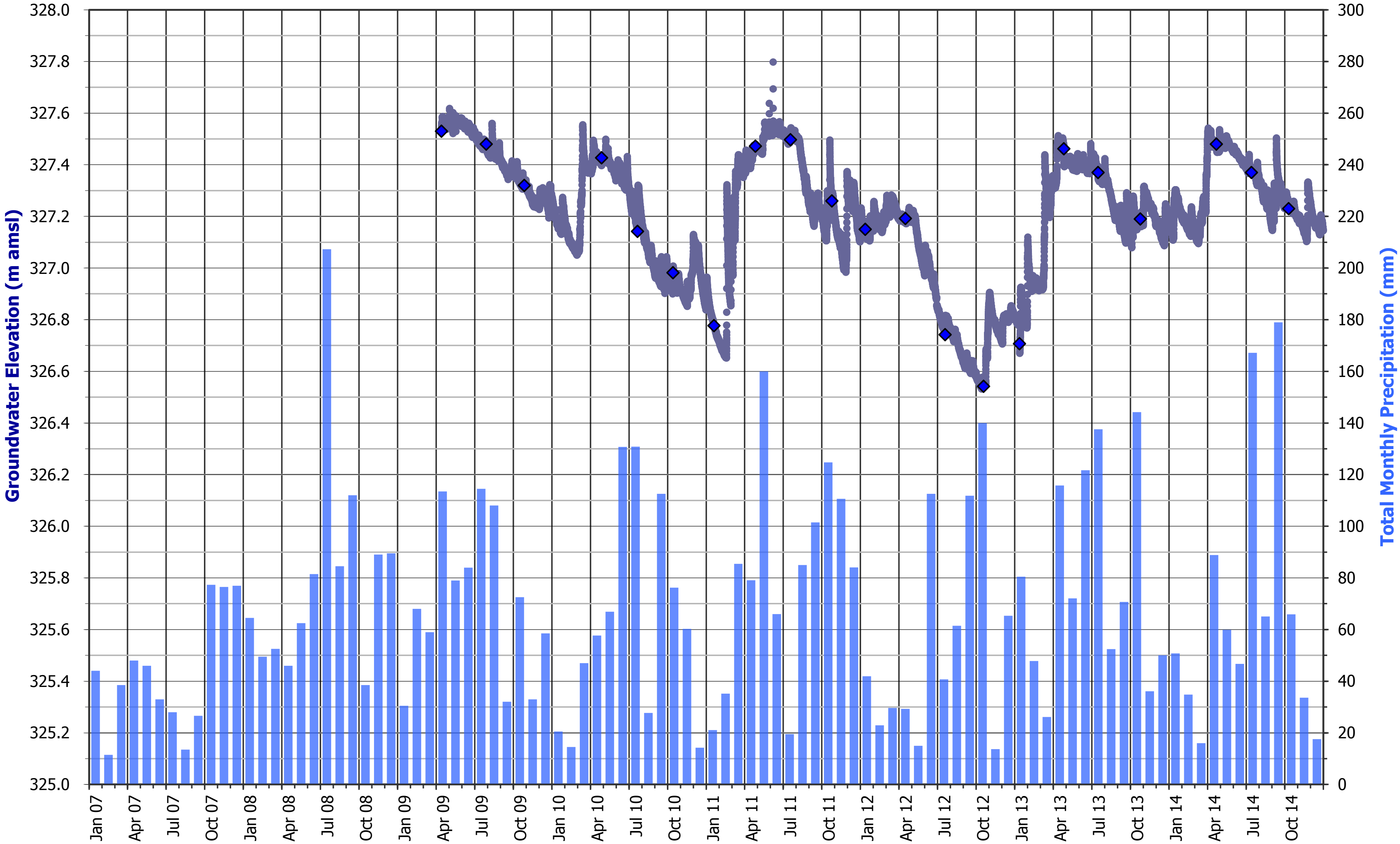
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 3 - Core PSW** **Graph G 21a**

Groundwater Elevation & Precipitation - PZ-1D (April 09 to December 14)



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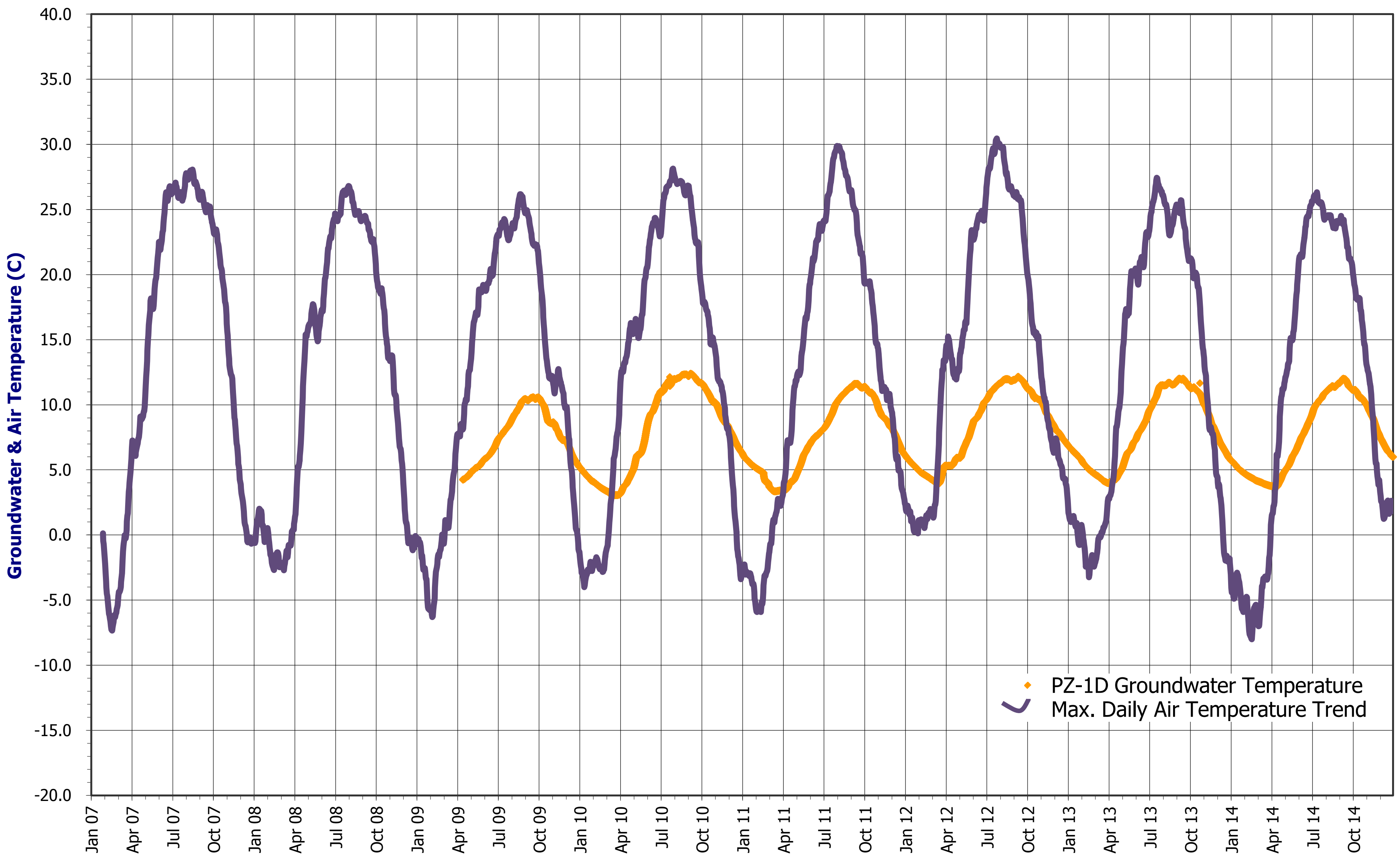
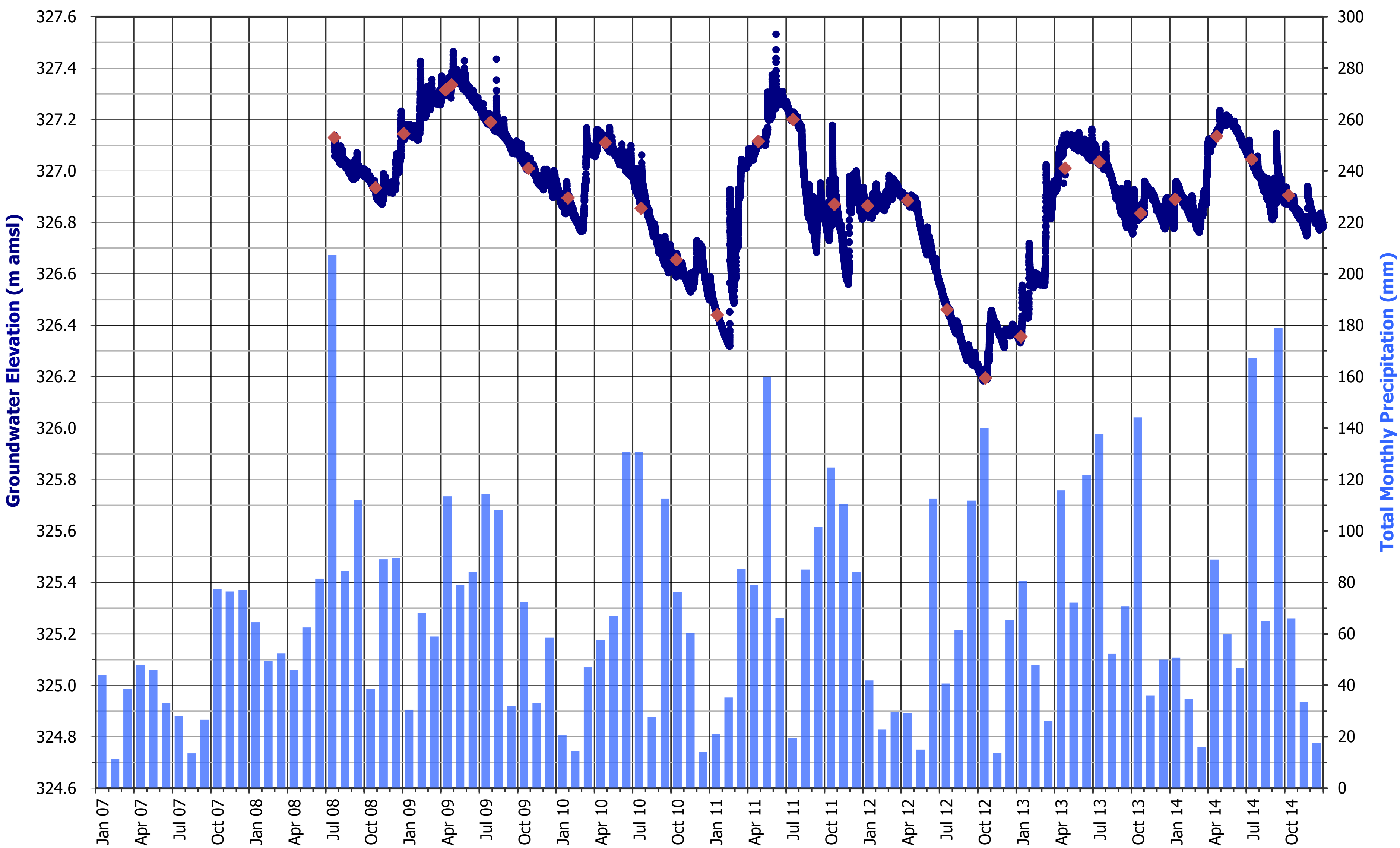
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 3 - Core PSW** **Graph G 22**

Groundwater & Maximum Daily Air Temperature - PZ-1D (April 09 to December 14)



Groundwater Elevation & Precipitation - MW121A (July 08 to December 14)



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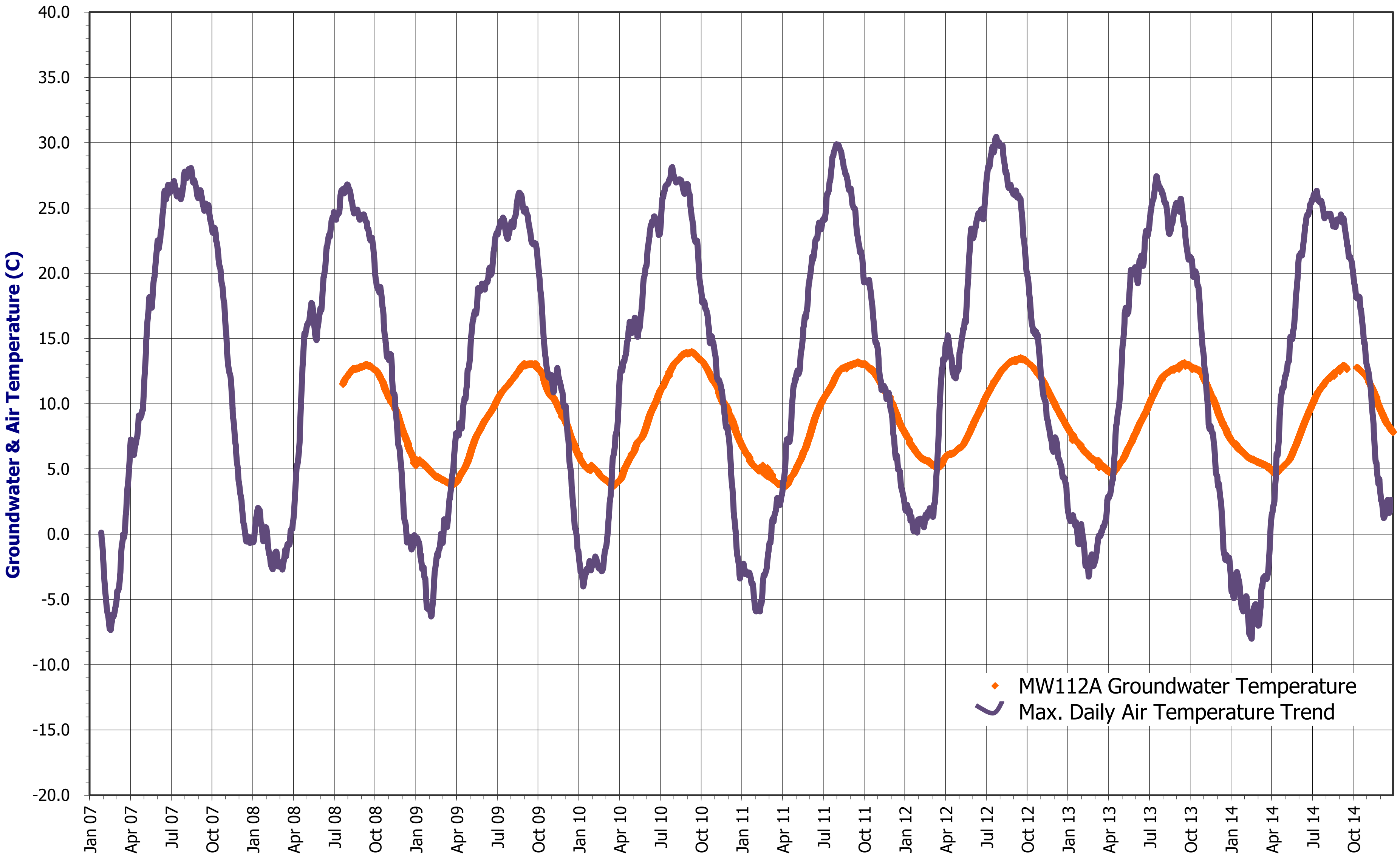
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Core PSW** **Graph G 23**

Groundwater & Maximum Daily Air Temperature - MW121A (July 08 to December 14)



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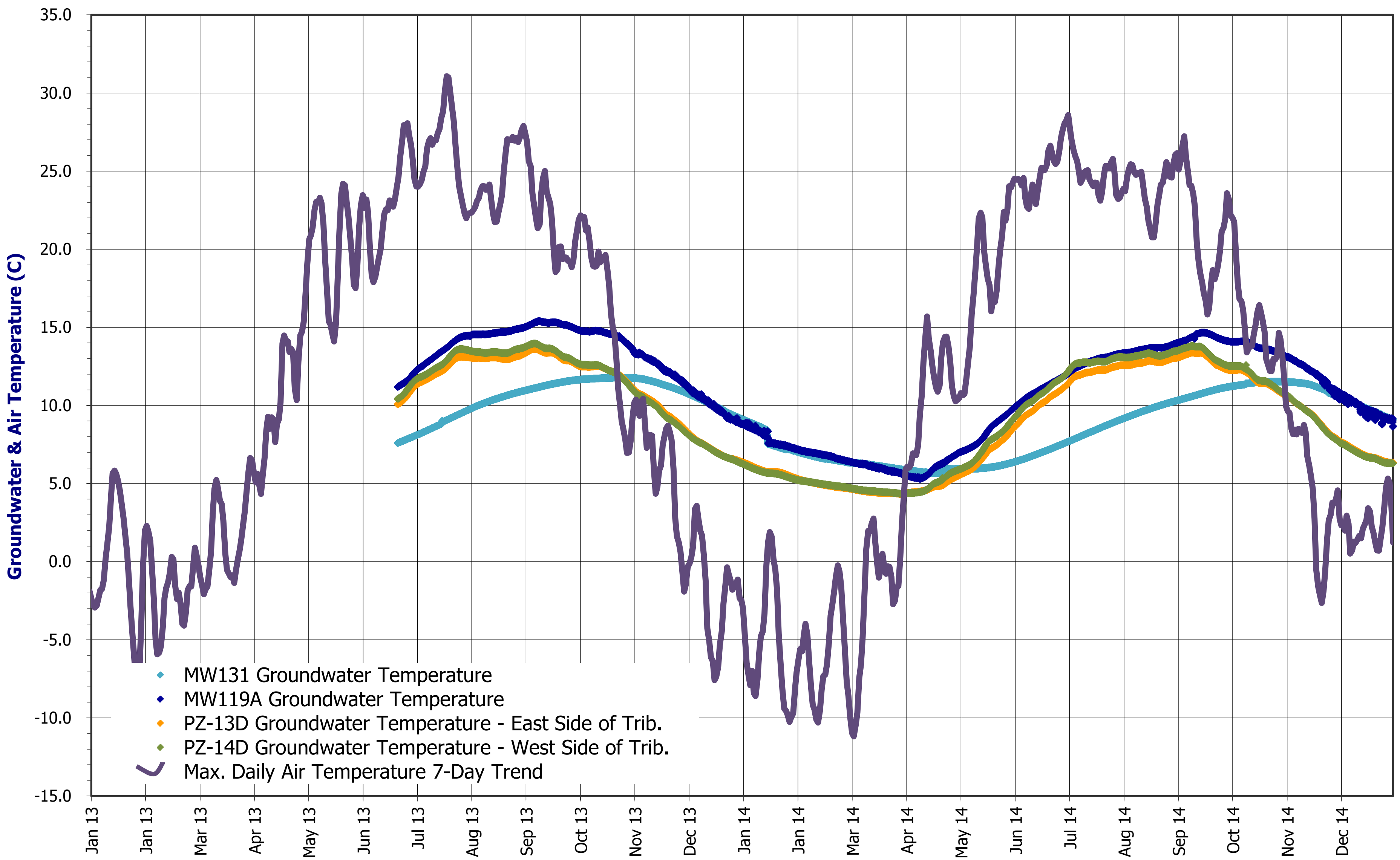
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Core PSW** **Graph G 23a**

Groundwater & Maximum Daily Air Temperature - PZ-13D, PZ-14D, MW119A & MW131 (June 13 to December 14)



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Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014

Phase 2 - Core PSW Graph G 24a

Appendix H

HCBP Perimeter Groundwater Monitoring 2007 – 2014

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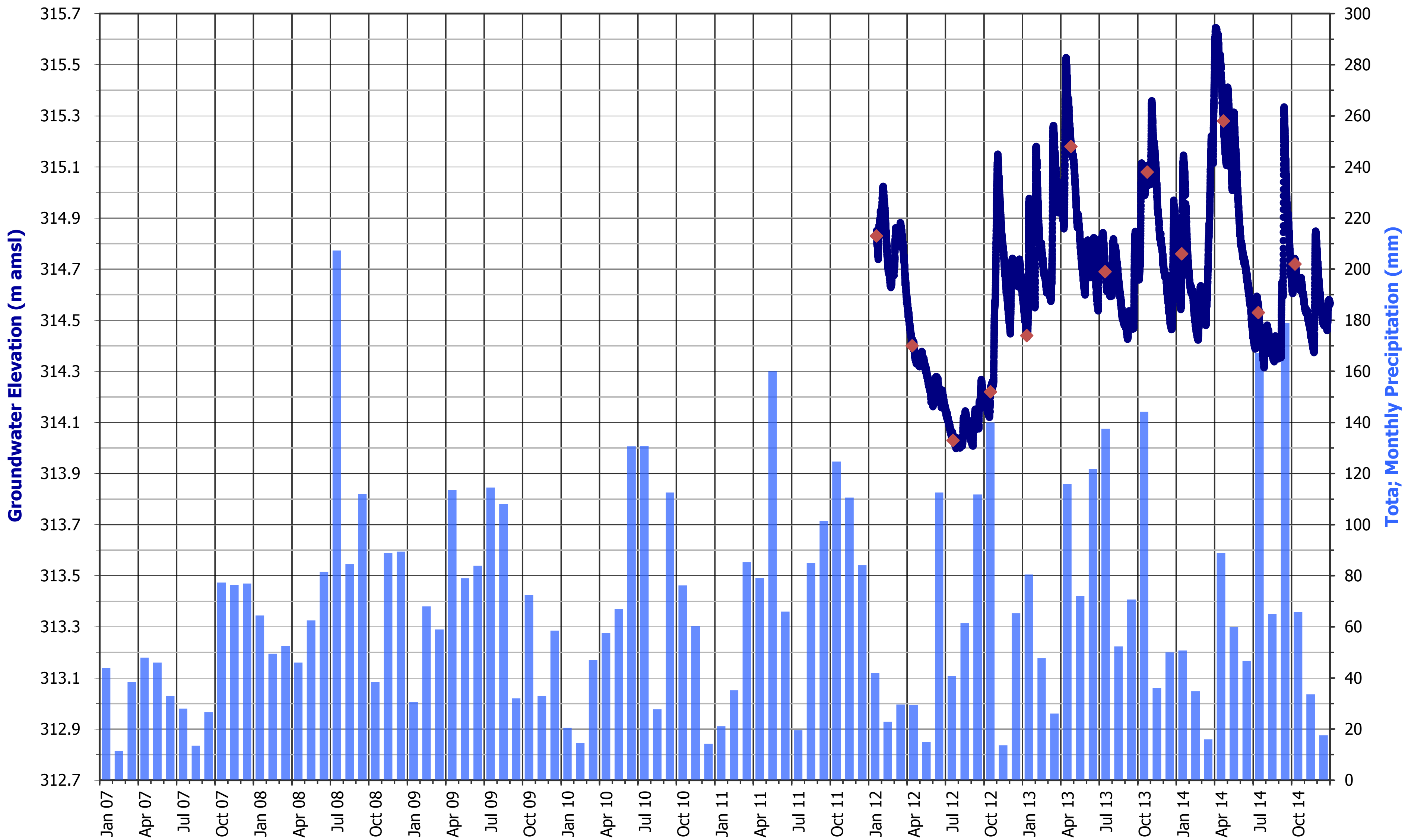
Groundwater Elevation & Precipitation - MW125 (January 12 to December 14)



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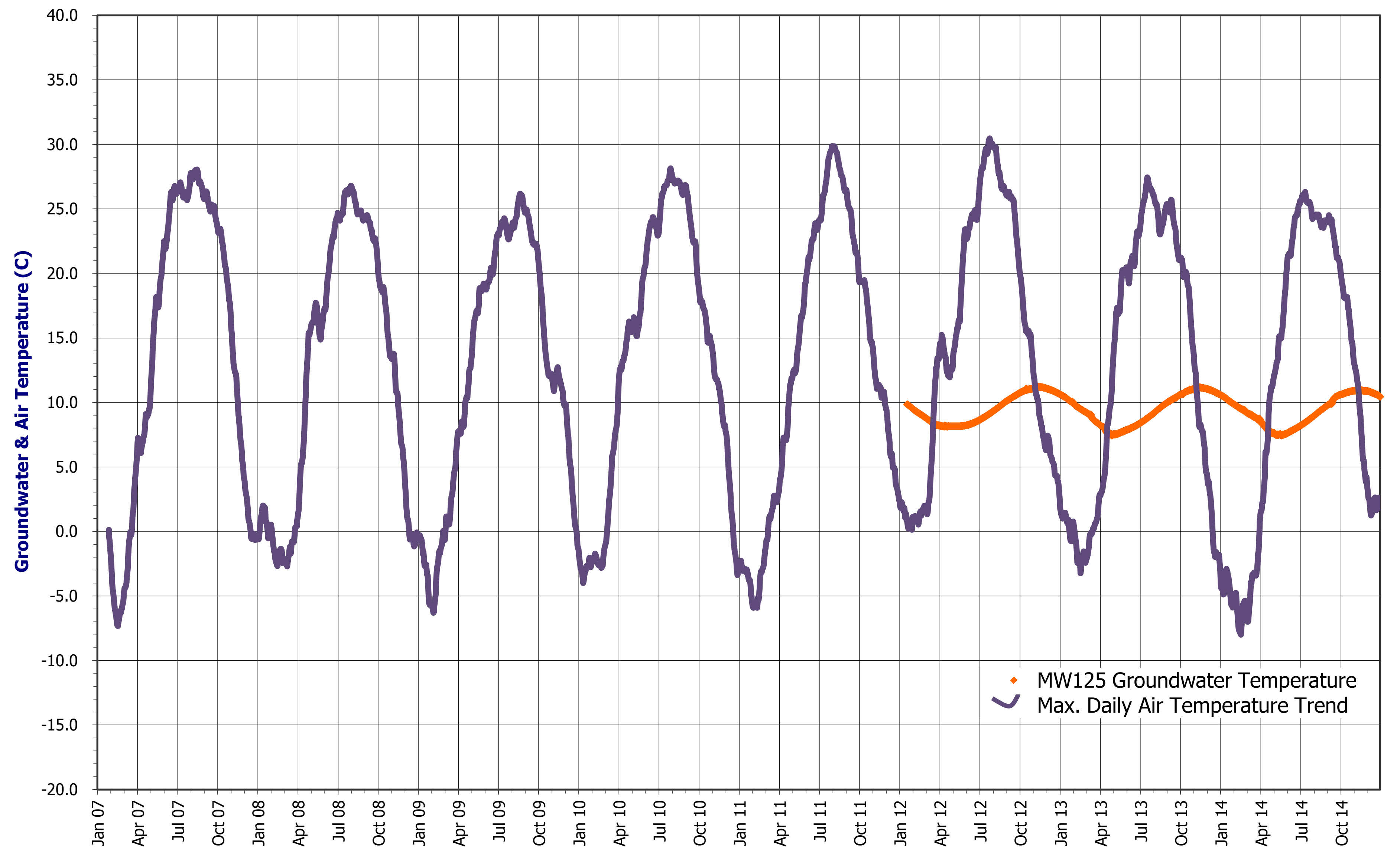
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Perimeter** **Graph H 1**

Groundwater & Maximum Daily Air Temperature - MW125 (January 12 to December 14)



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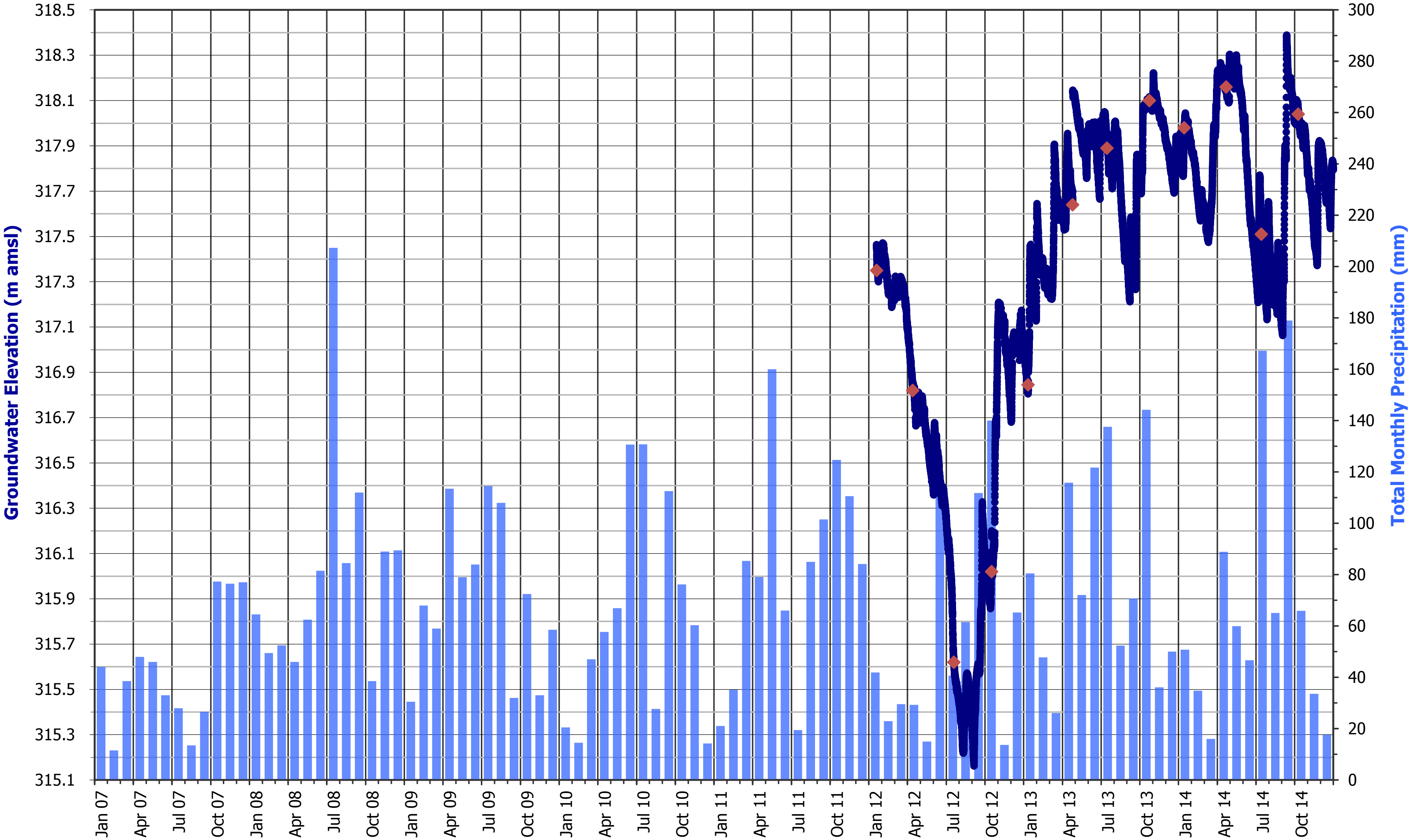
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Perimeter** **Graph H 1a**

Groundwater Elevation & Precipitation - MW126 (January 12 to December 14)

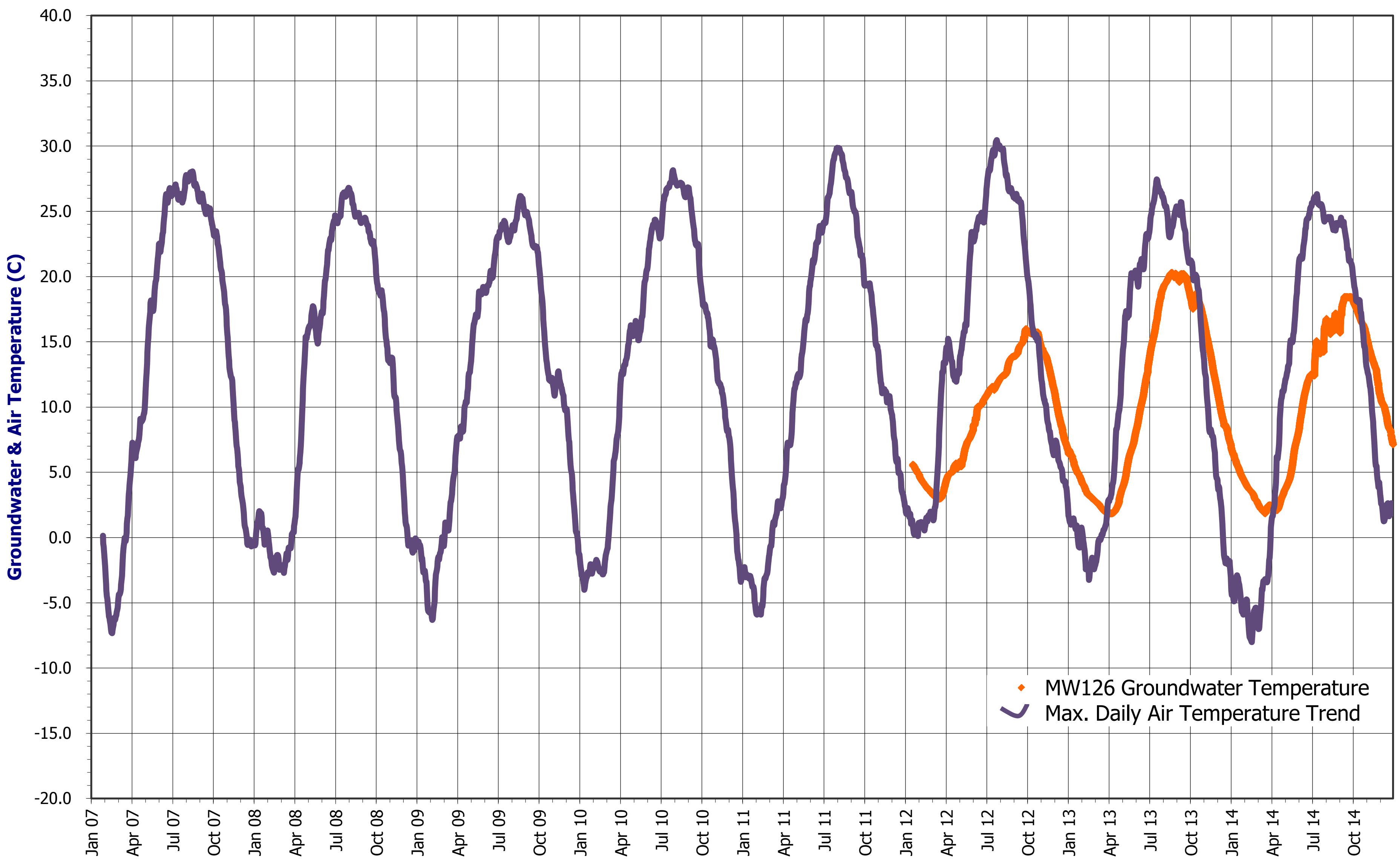


Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Perimeter** **Graph H 2**

Groundwater & Maximum Daily Air Temperature - MW126 (January 12 to December 14)



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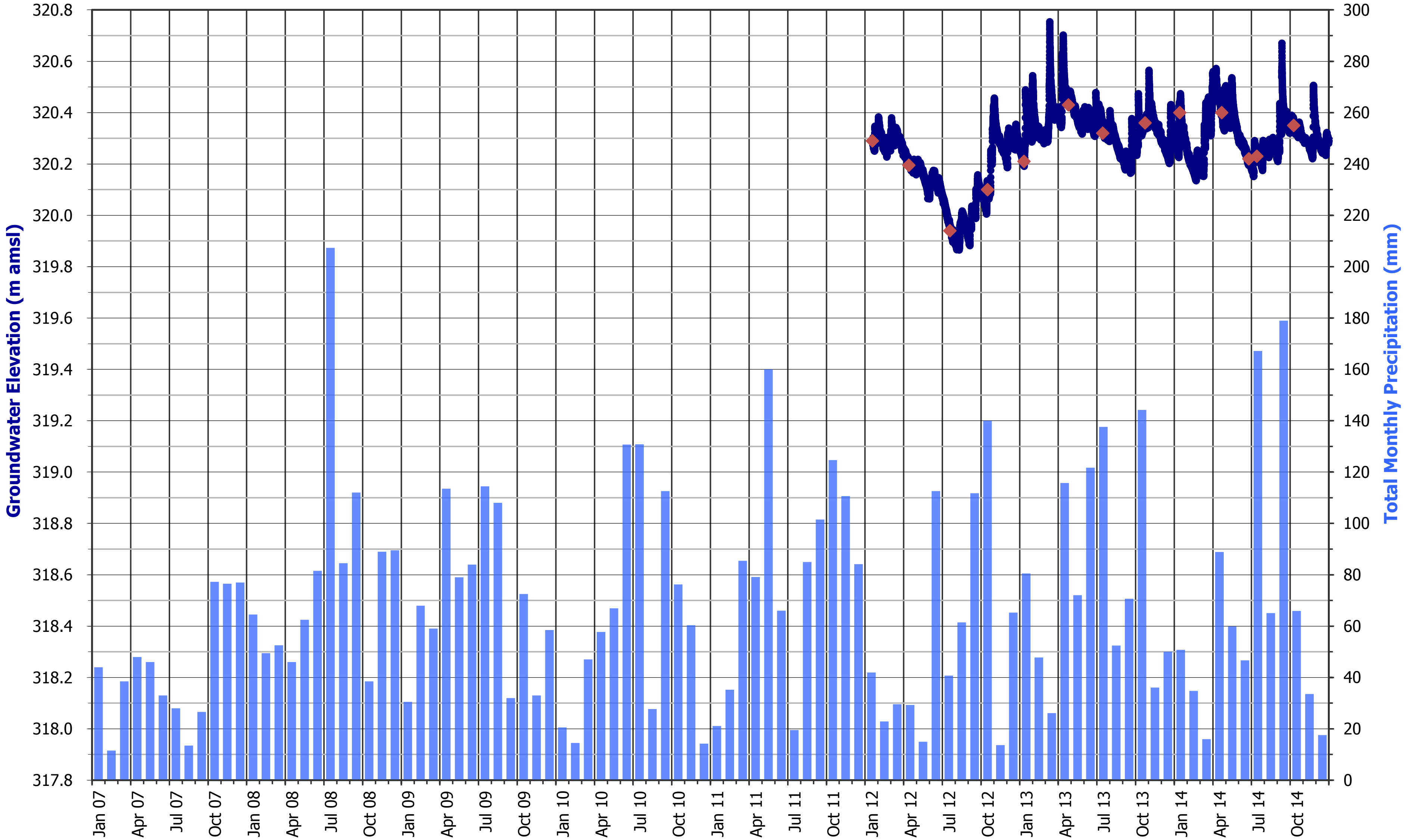
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Perimeter** **Graph H 2a**

Groundwater Elevation & Precipitation - MW128 (January 12 to December 14)



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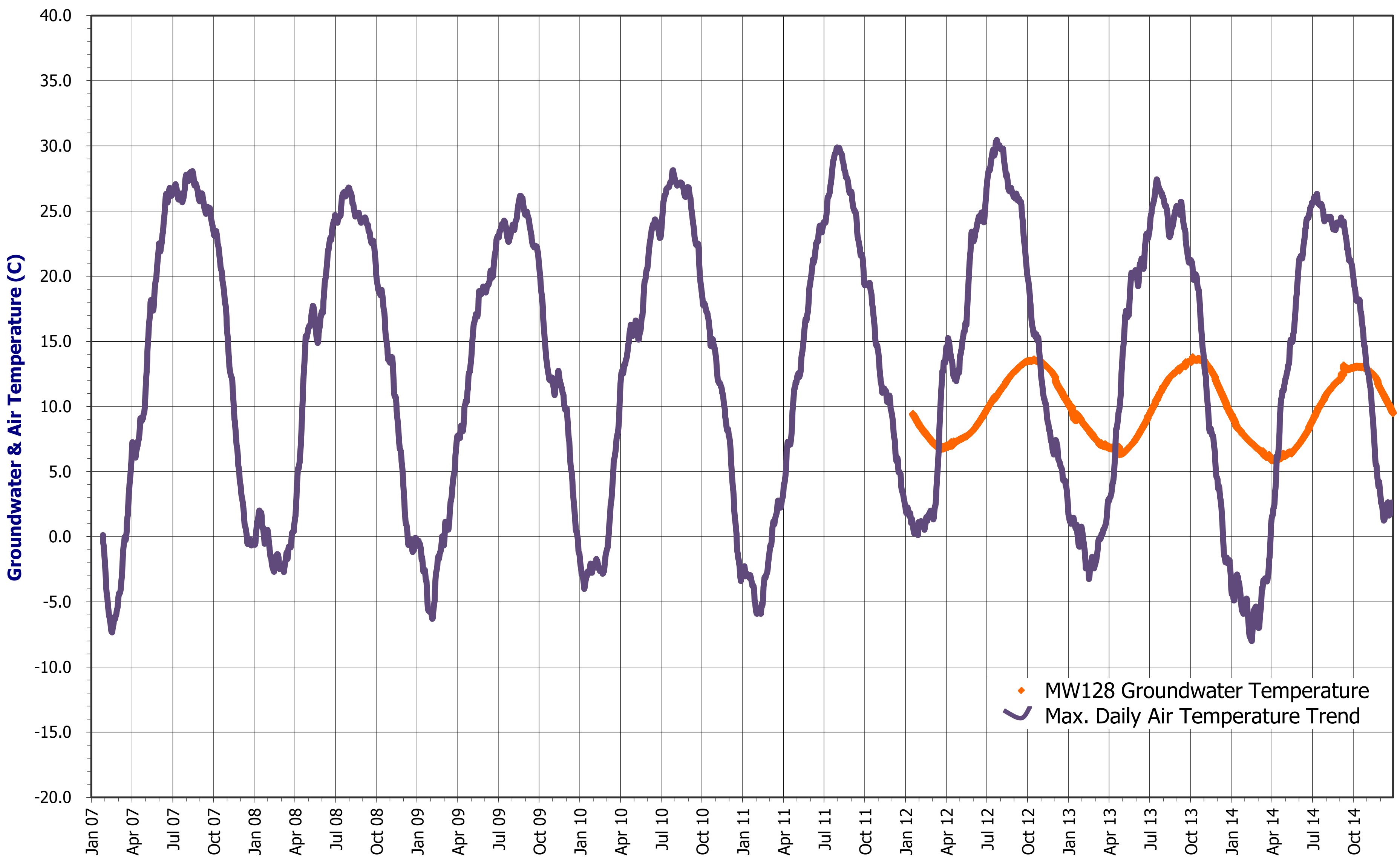
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Perimeter** **Graph H 3**

Groundwater & Maximum Daily Air Temperature - MW128 (January 12 to December 14)



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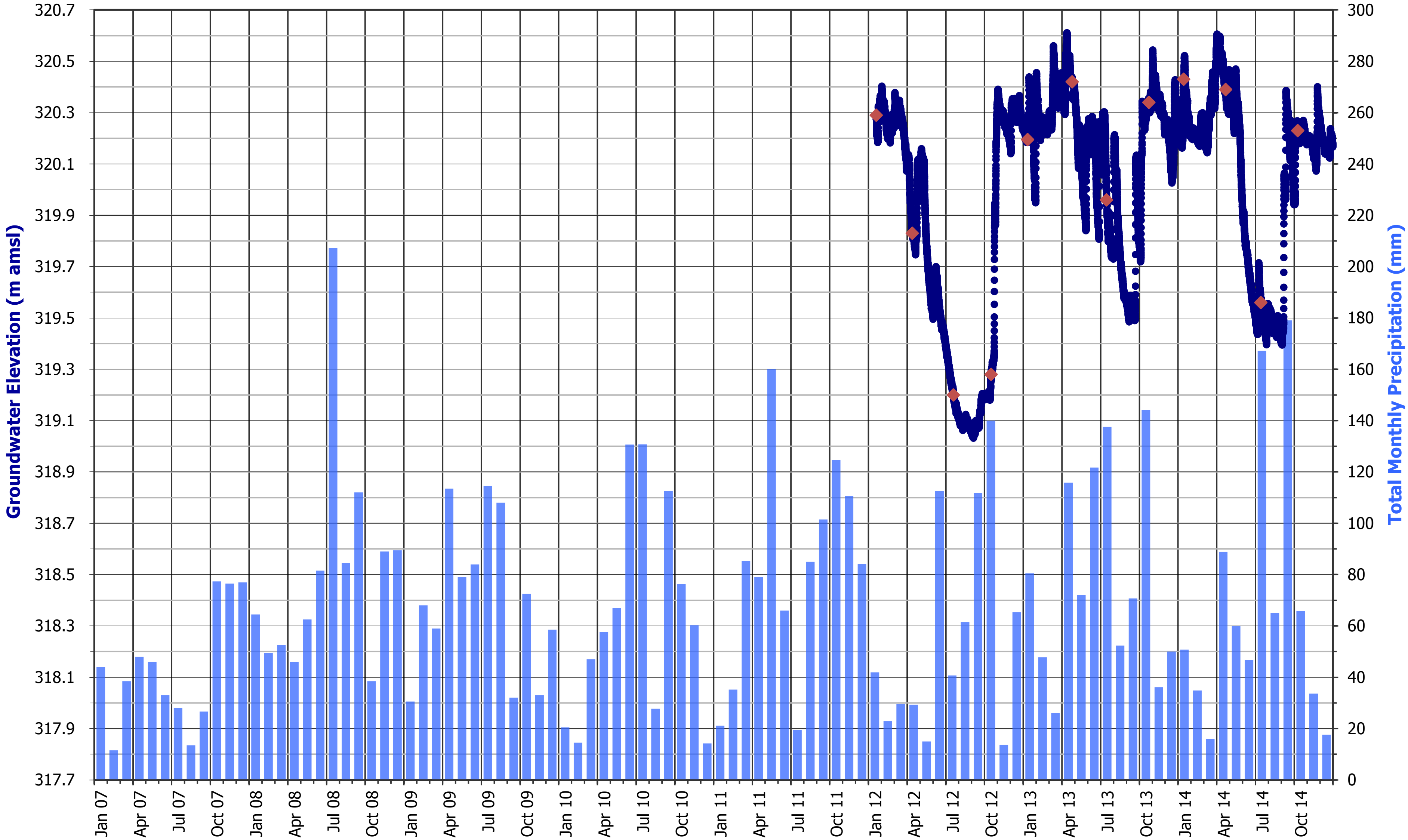
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Perimeter** **Graph H 3a**

Groundwater Elevation & Precipitation - MW124 (January 12 to December 14)



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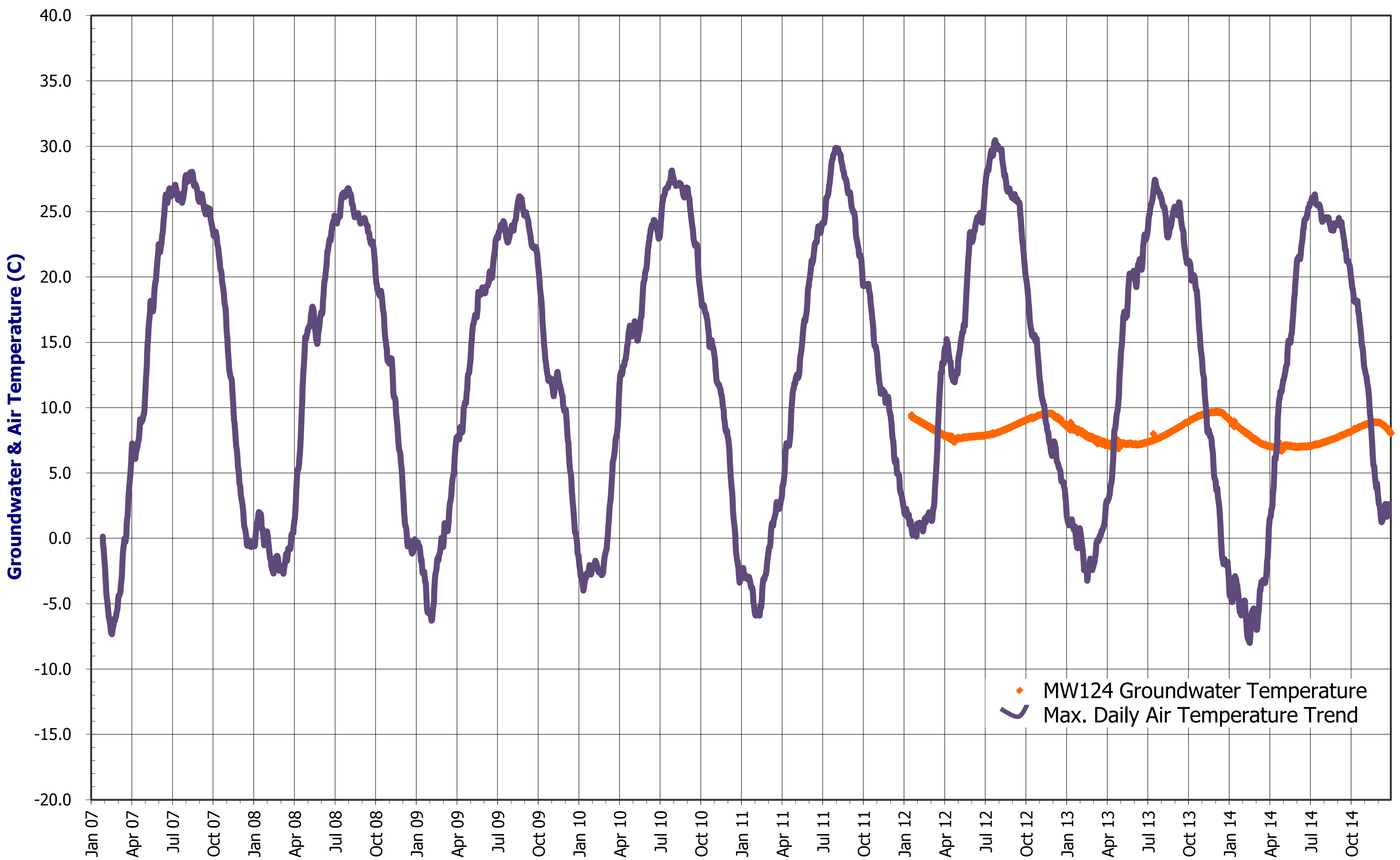
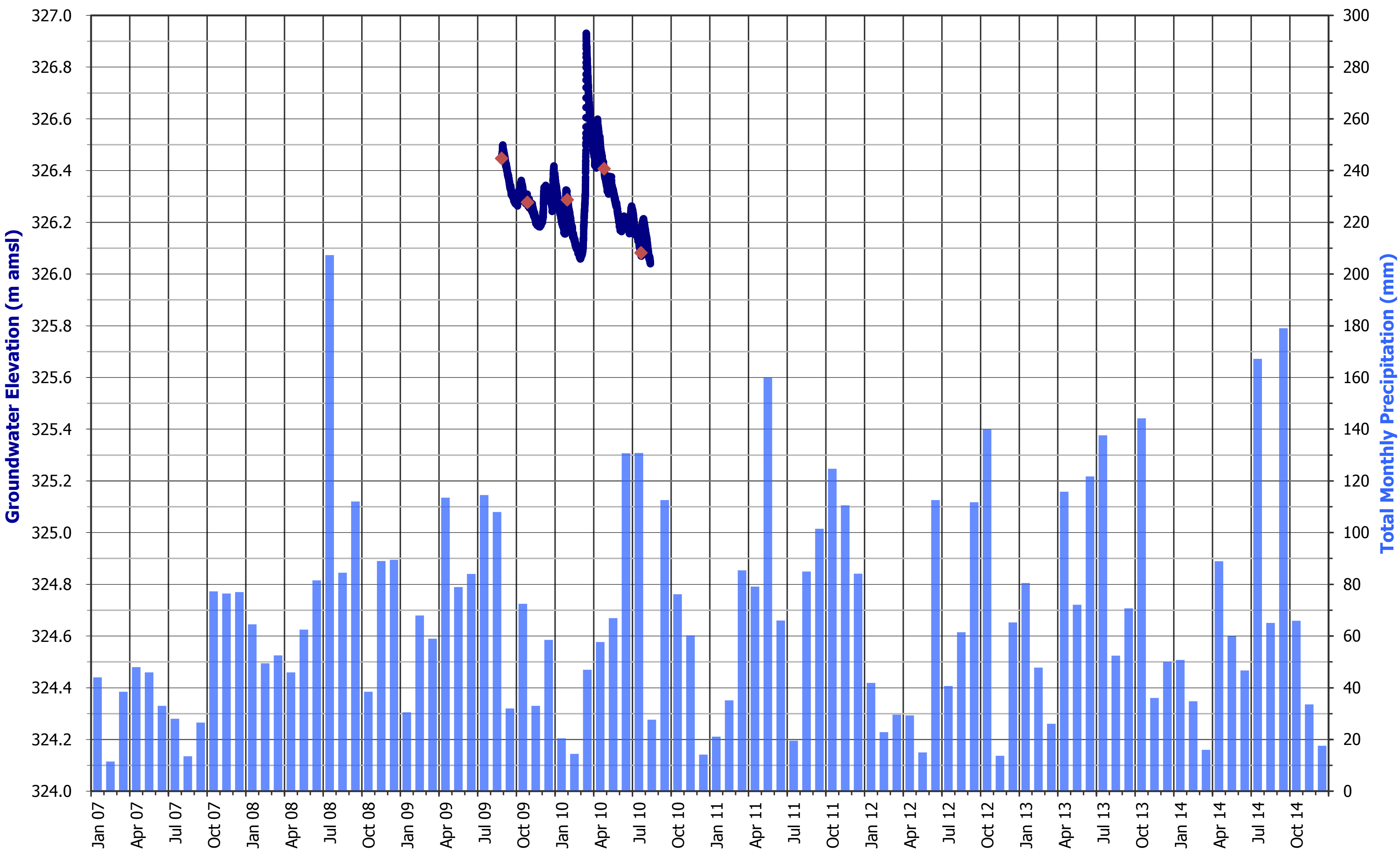
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 1 - Perimeter** **Graph H 4**

Groundwater & Maximum Daily Air Temperature - MW124 (January 12 to December 14)



Groundwater Elevation & Precipitation - MW106 (August 09 to August 10) Abandoned 2012



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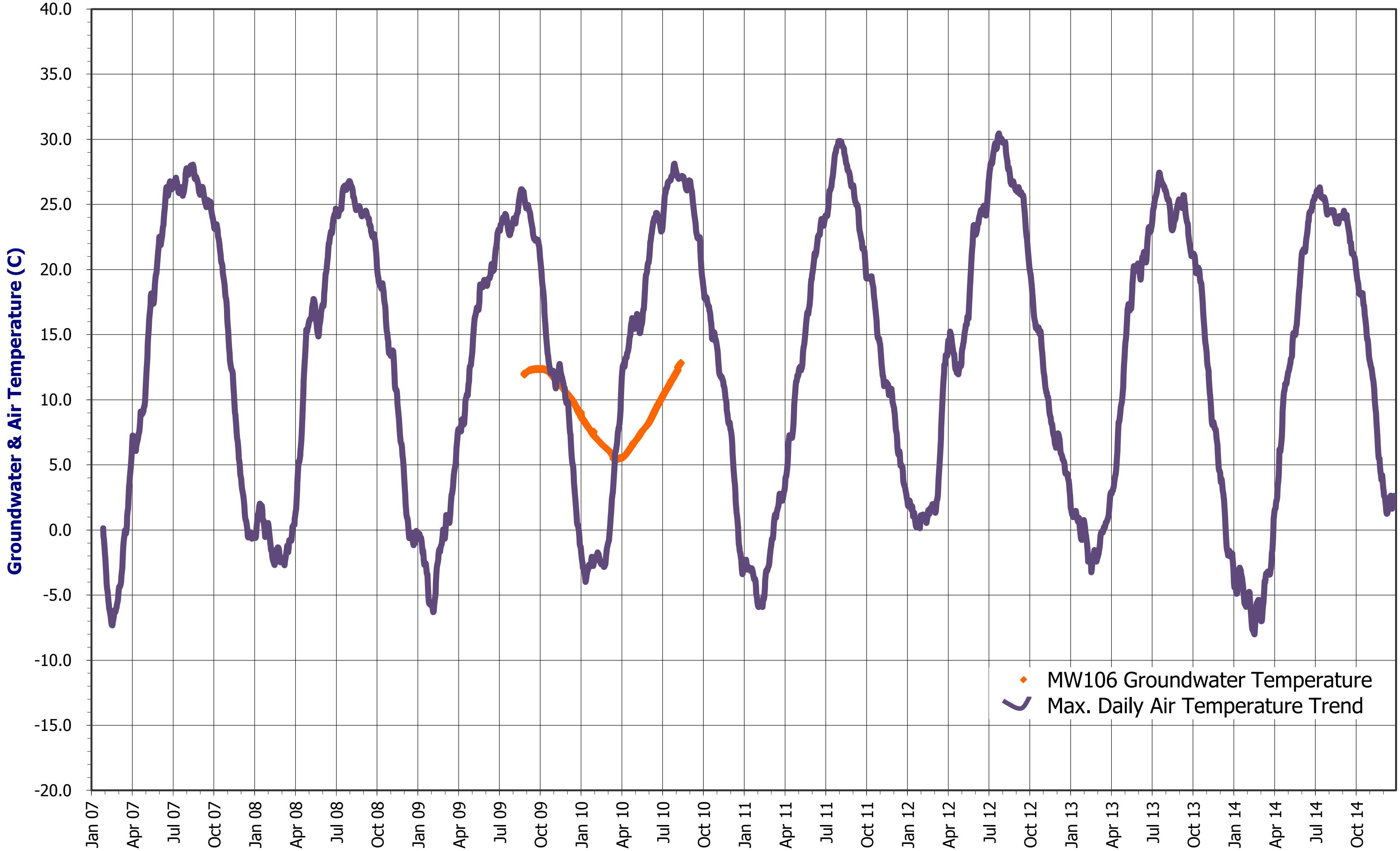
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Perimeter** **Graph H 5**

Groundwater & Maximum Daily Air Temperature - MW106 (August 09 to August 10) Abandoned 2012



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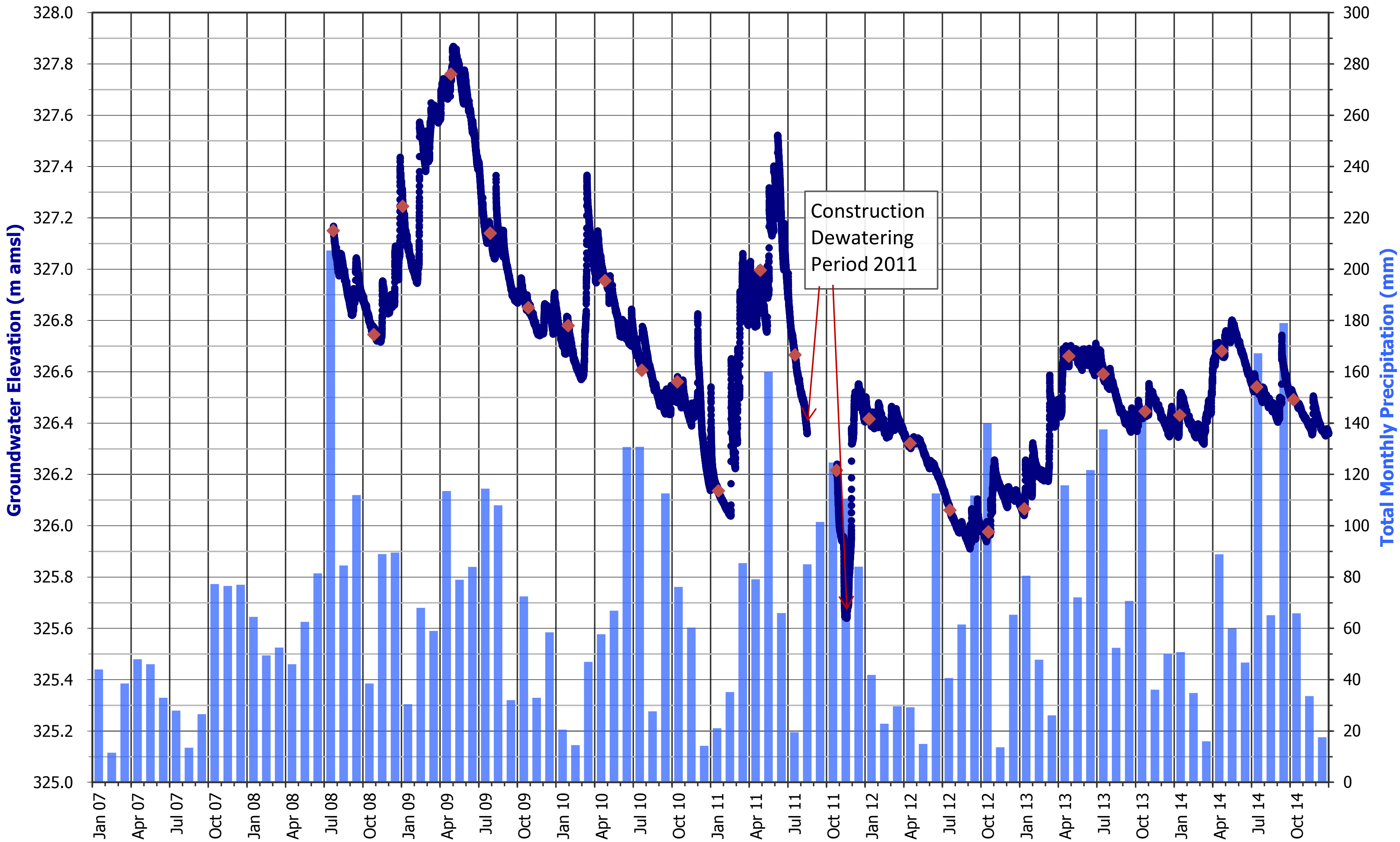
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Perimeter** **Graph H 5a**

Groundwater Elevation & Precipitation - MW107 (July 08 to December 14)



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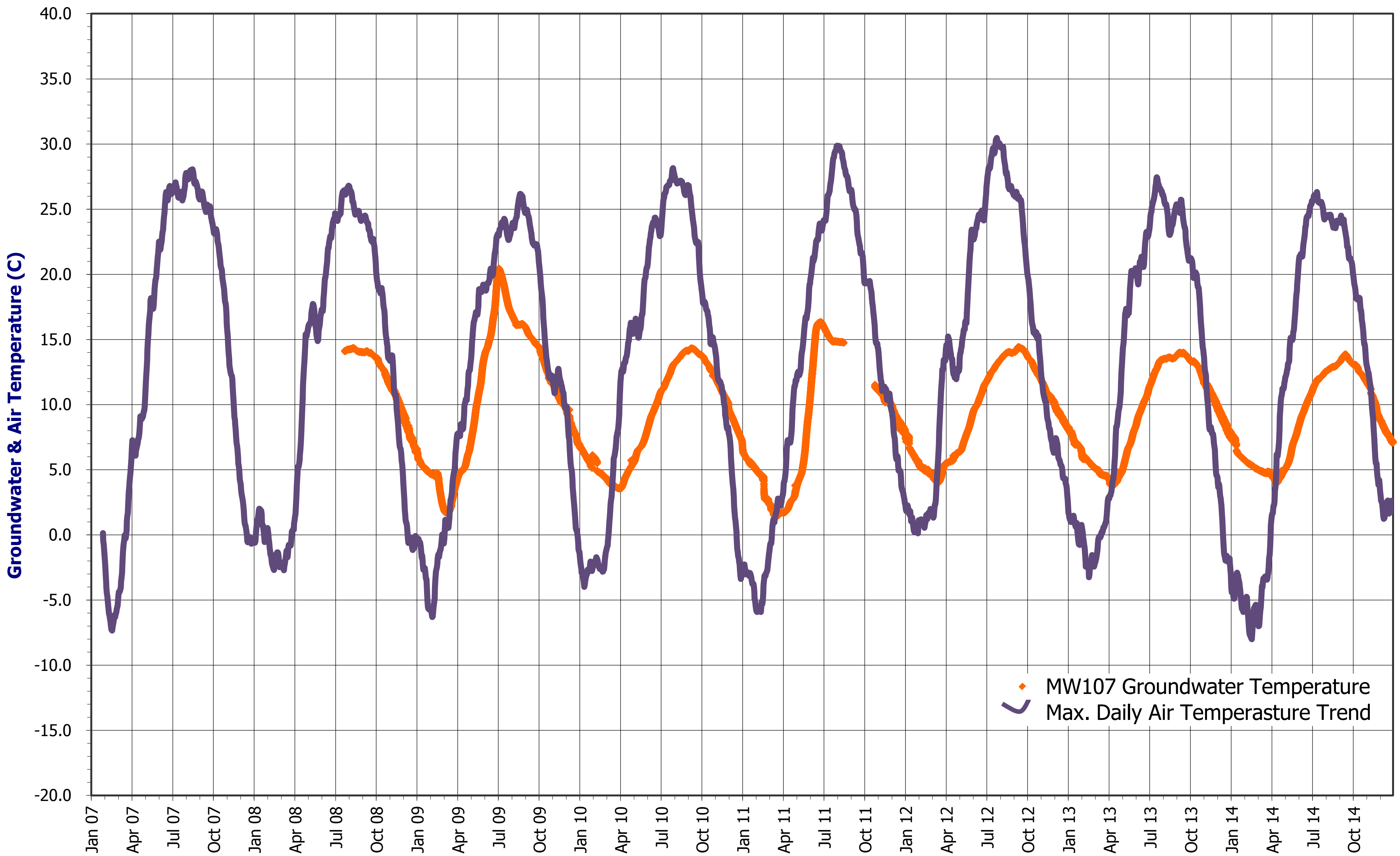
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Perimeter** **Graph H 6**

Groundwater & Maximum Daily Air Temperature - MW107 (July 08 to December 14)



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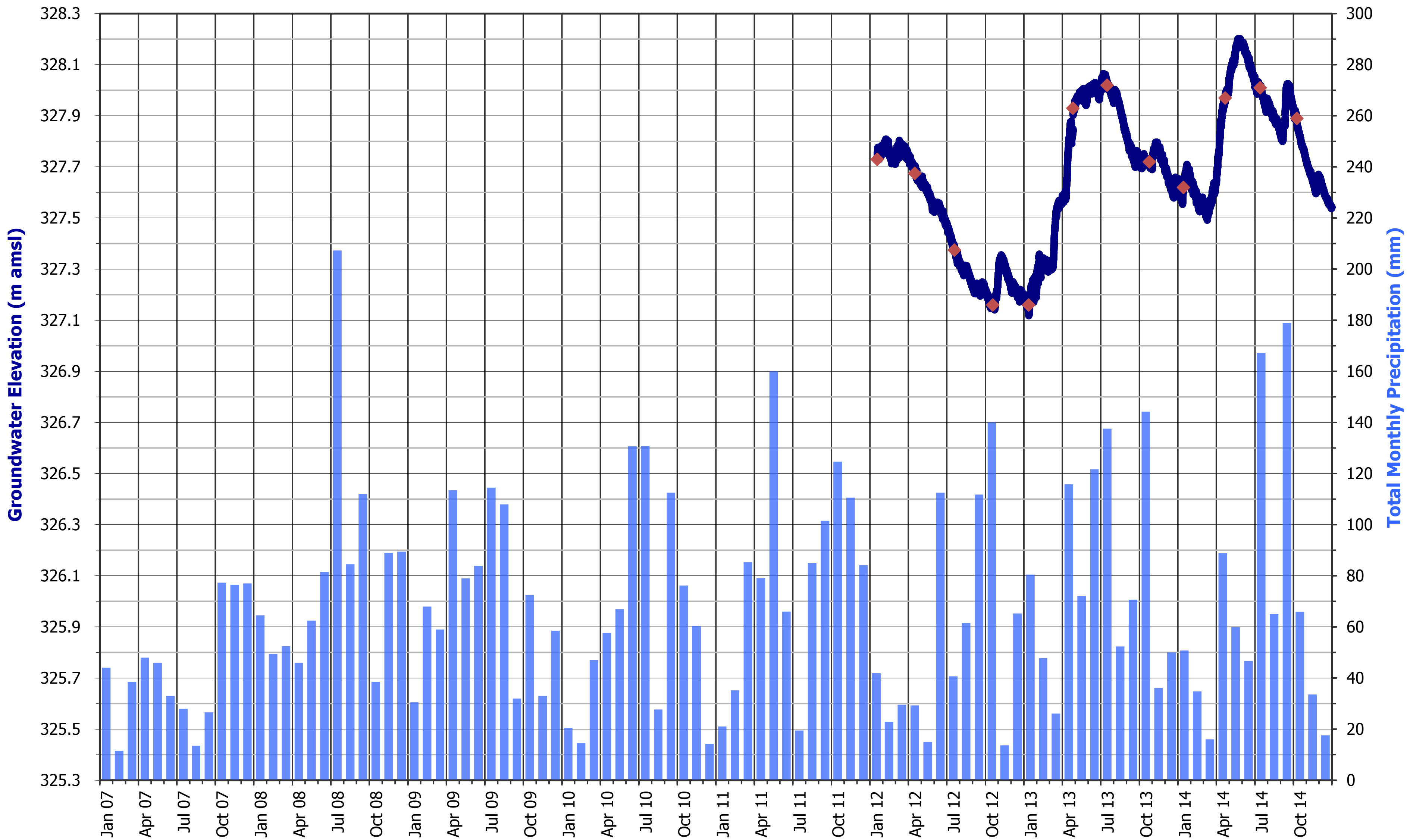
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Perimeter** **Graph H 6a**

Groundwater Elevation & Precipitation - MW132 (January 12 to December 14)



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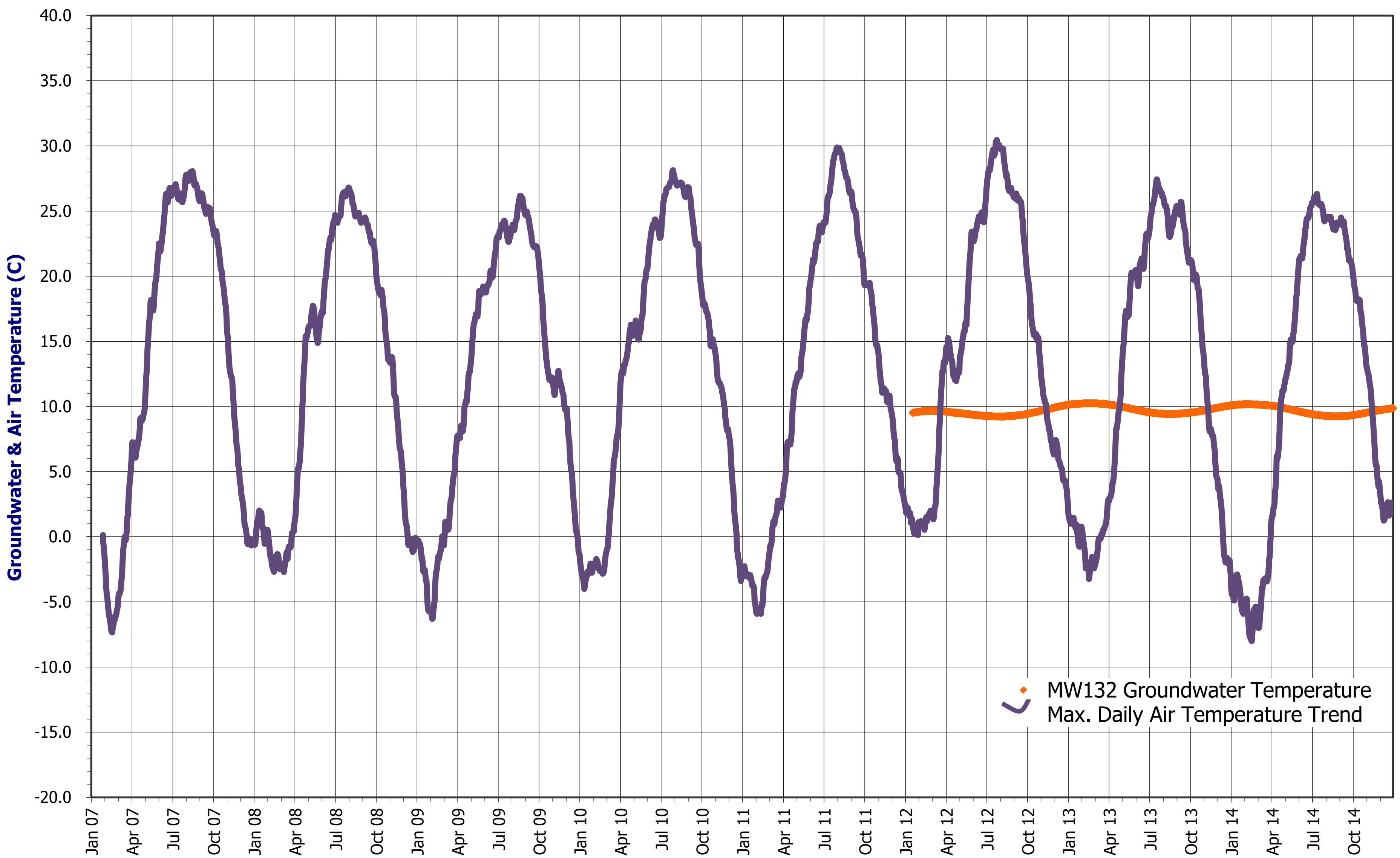
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Perimeter** **Graph H 7**

Groundwater & Maximum Daily Air Temperature - MW132 (January 12 to December 14)



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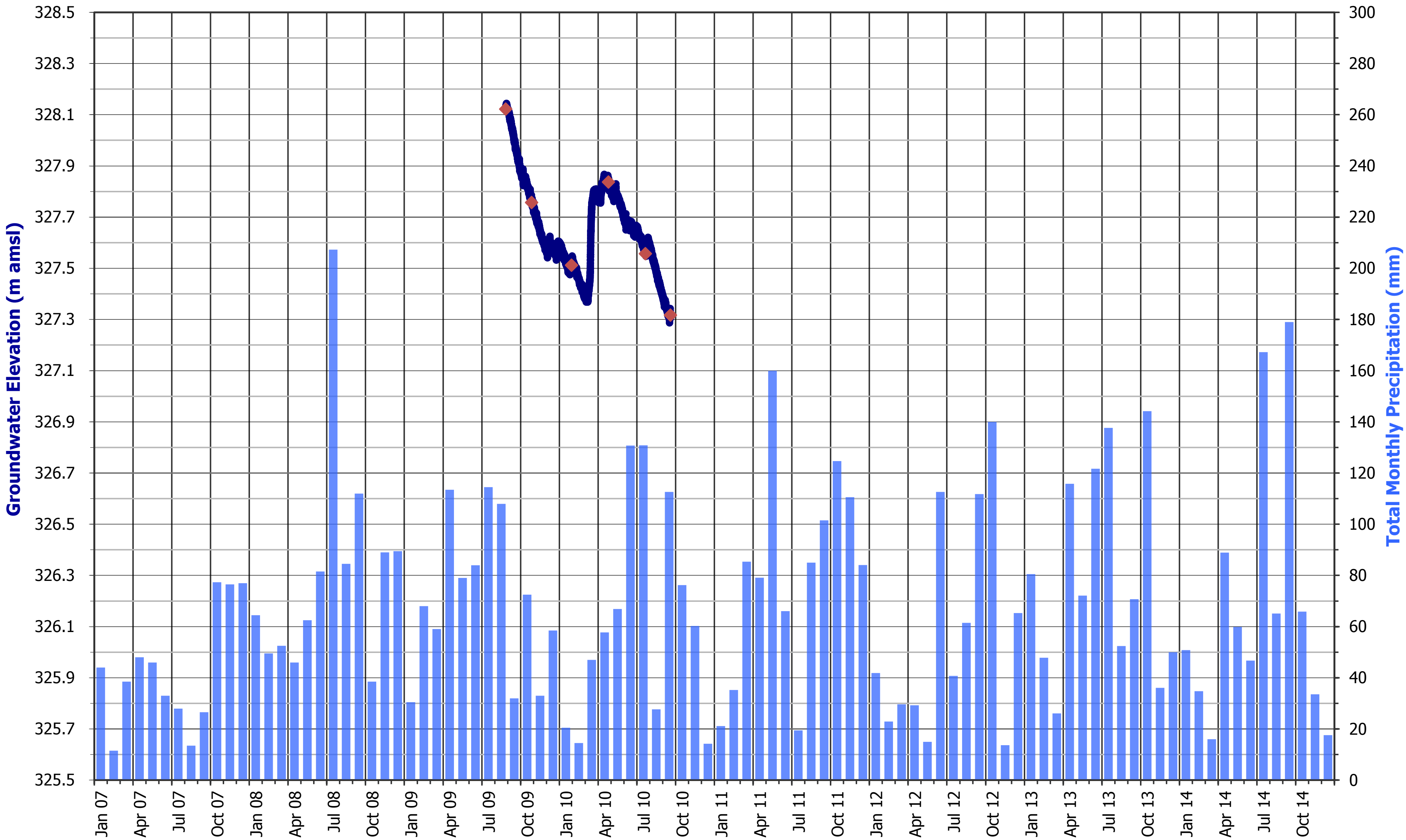
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Perimeter** **Graph H 7a**

Groundwater Elevation & Precipitation - MW006 (August 09 to September 10) Abandoned 2010



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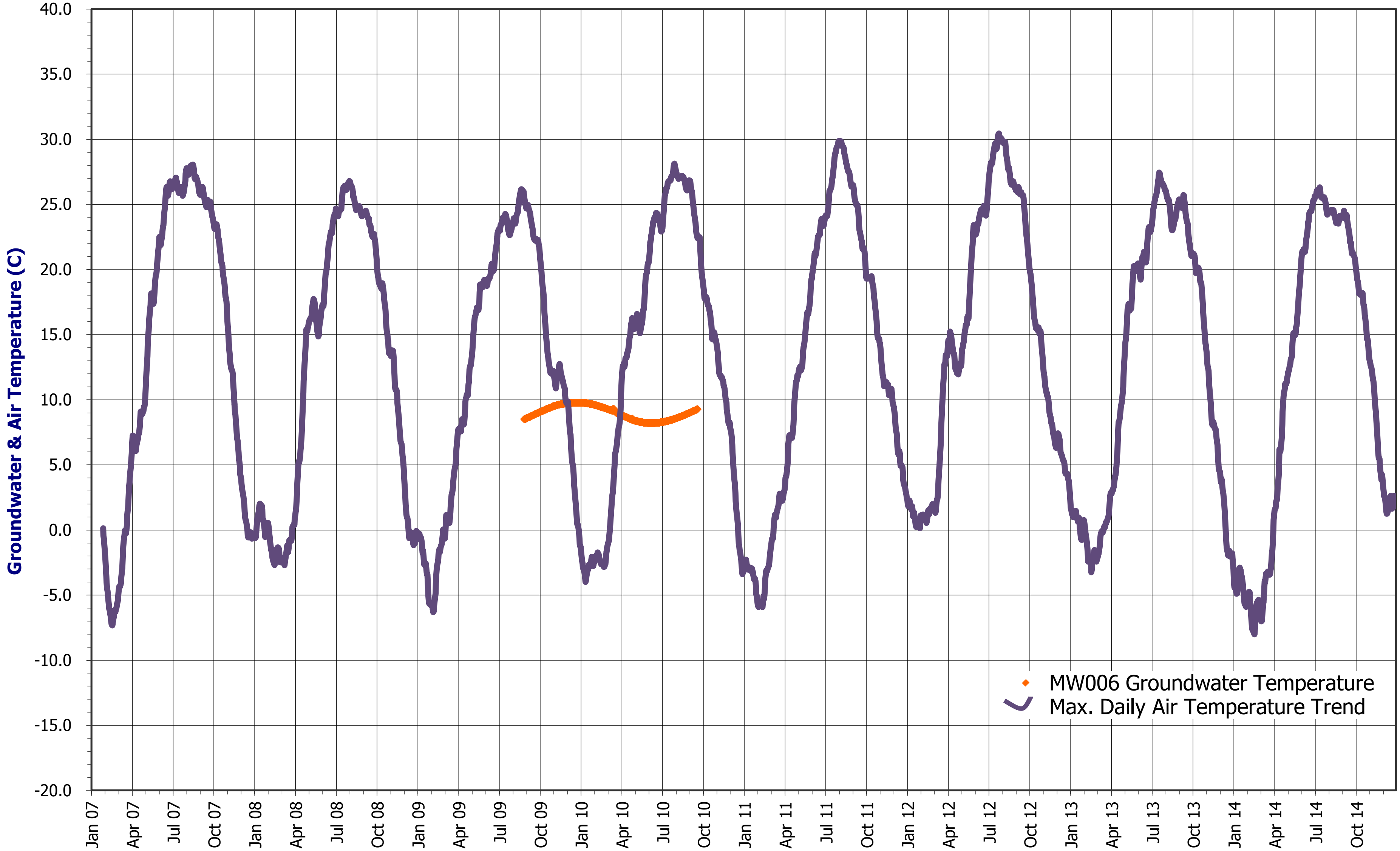
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Perimeter** **Graph H 8**

Groundwater & Maximum Daily Air Temperature - MW006 (August 09 to September 10) Abandoned 2010



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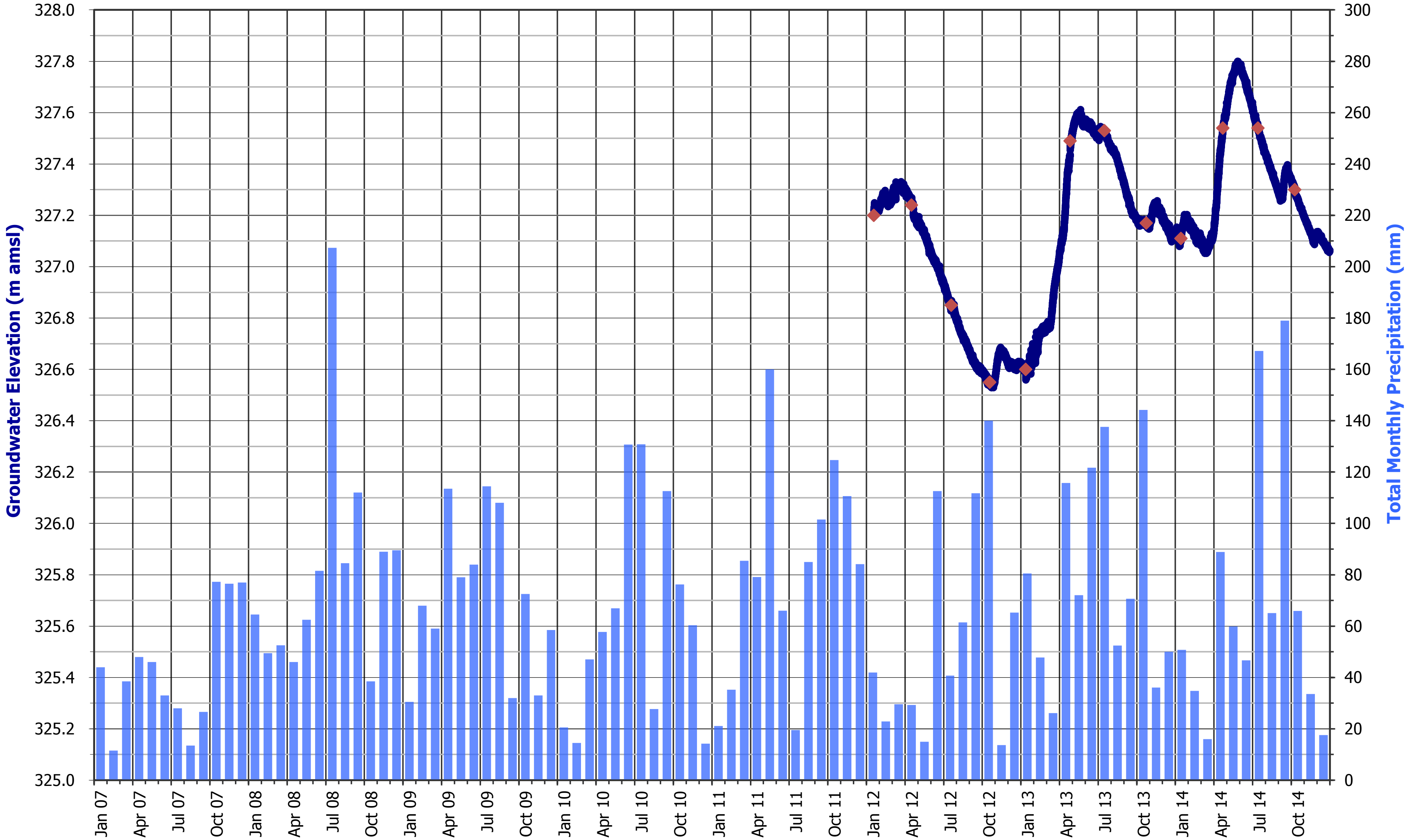
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Perimeter** **Graph H 8a**

Groundwater Elevation & Precipitation - MW135 (January 12 to December 14)



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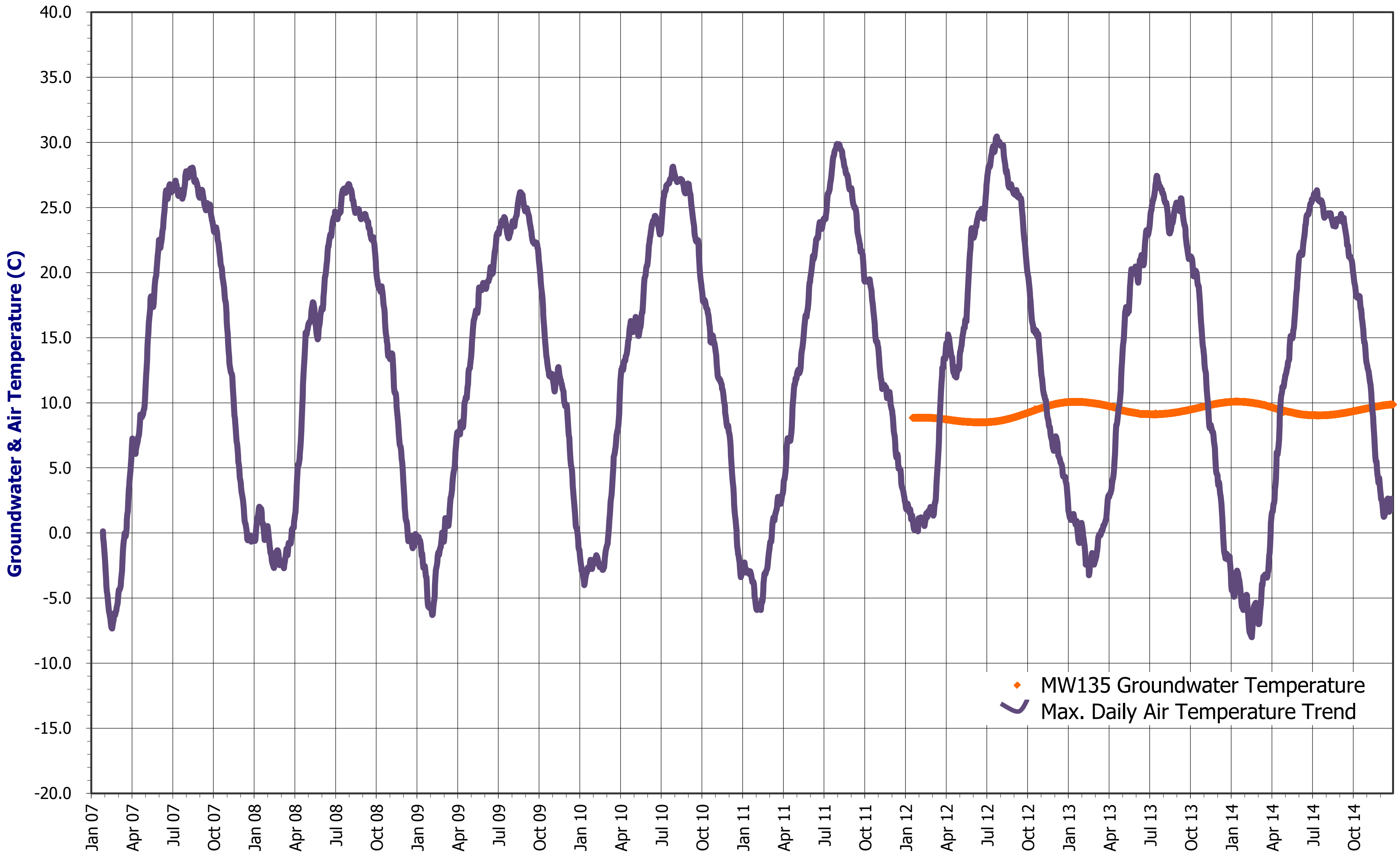
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Perimeter** **Graph H 9**

Groundwater & Maximum Daily Air Temperature - MW135 (January 12 to December 14)



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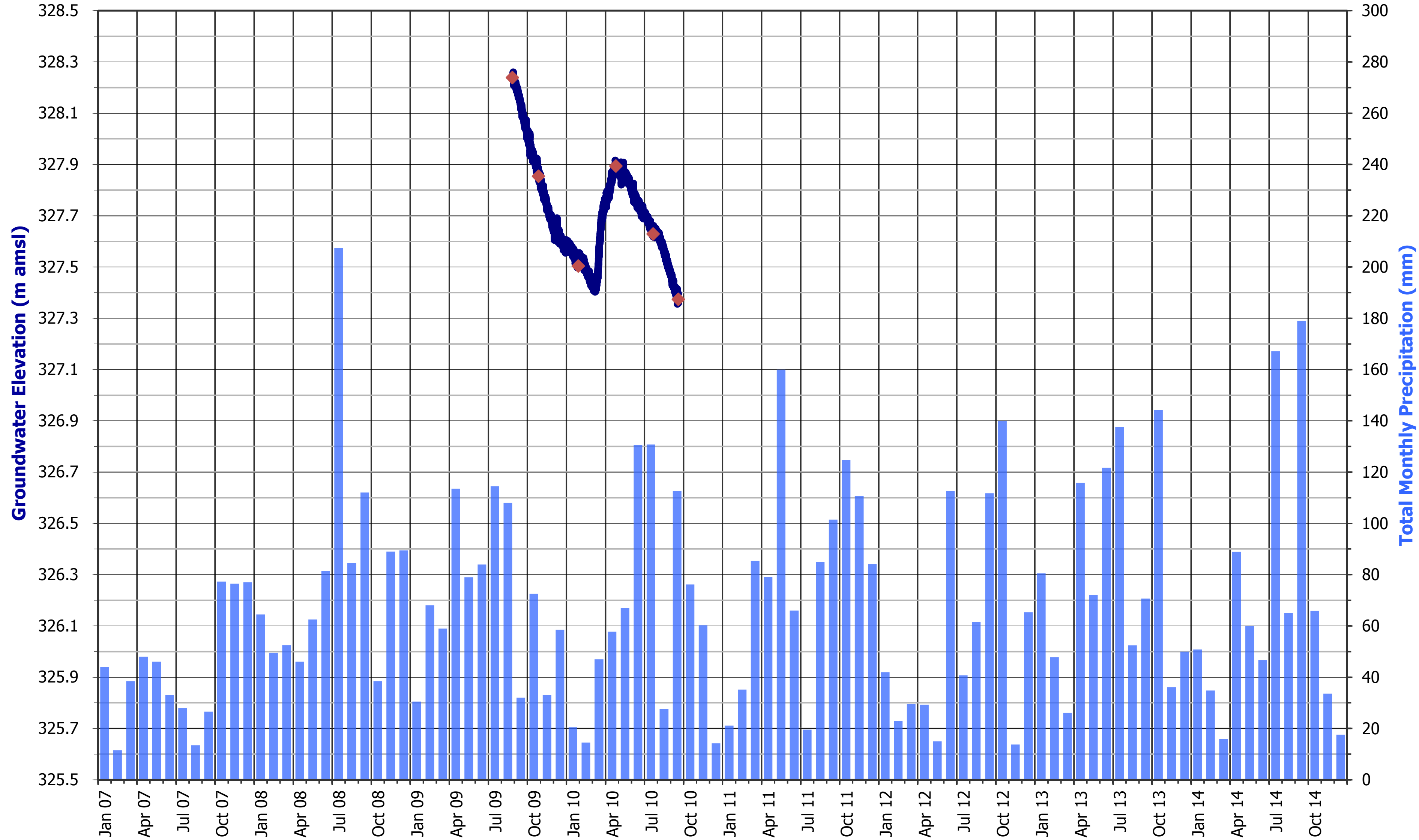
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Perimeter** **Graph H 9a**

Groundwater Elevation & Precipitation - MW005I (August 09 to September 10) Abandoned 2010



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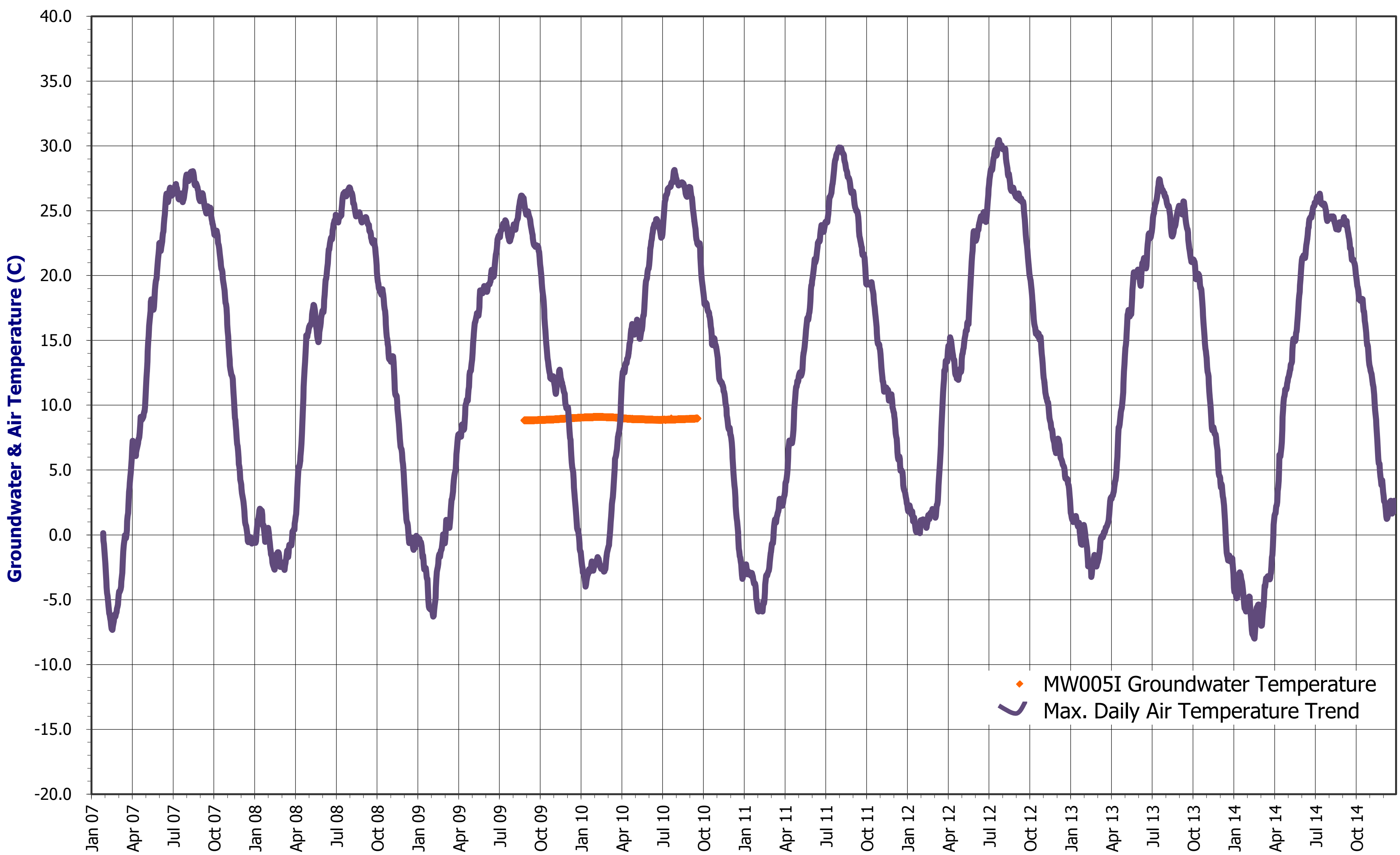
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Perimeter** **Graph H 10**

Groundwater & Maximum Daily Air Temperature - MW005I (August 09 to September 10) Abandoned 2010



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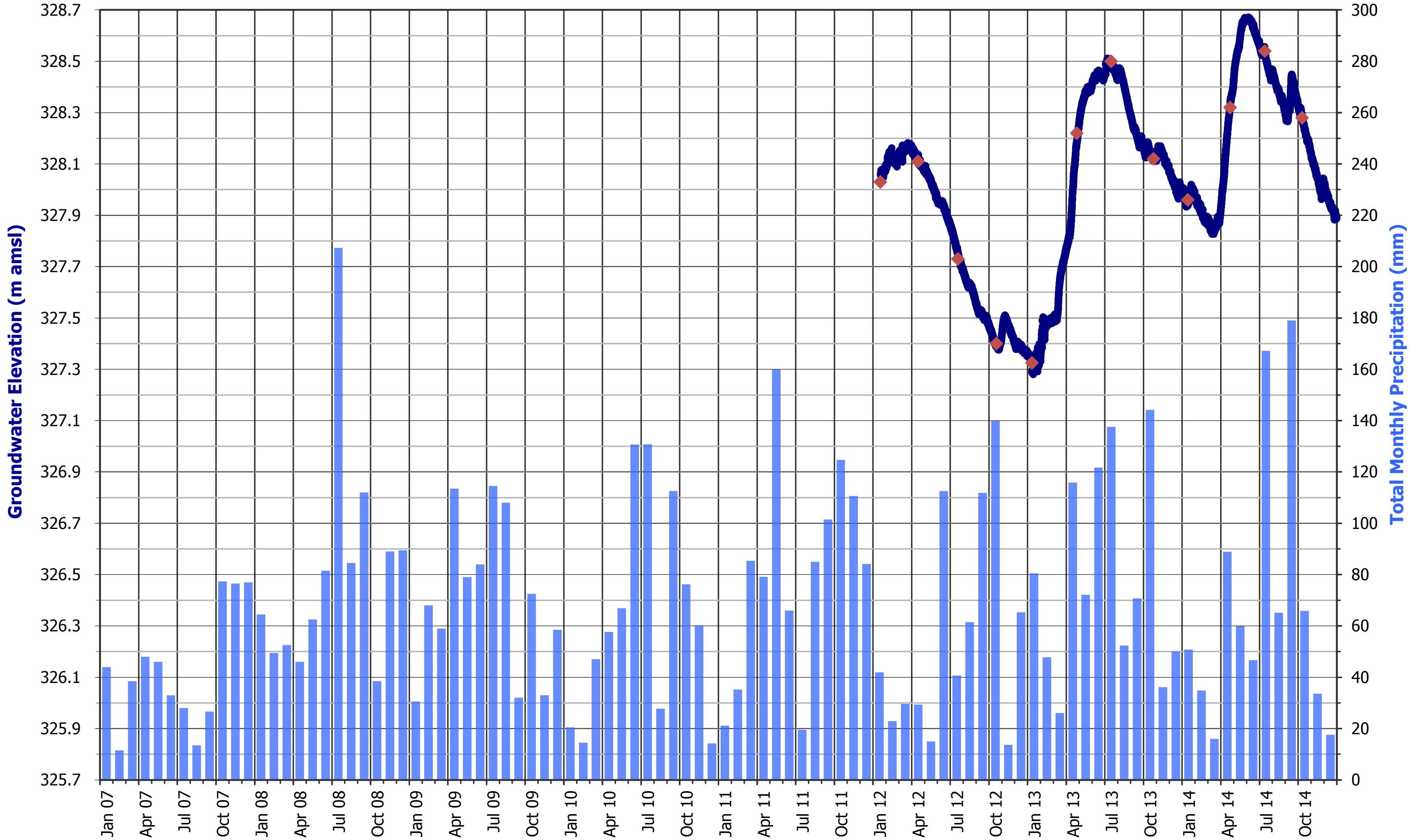
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Perimeter** **Graph H 10a**

Groundwater Elevation & Precipitation - MW133 (January 12 to December 14)



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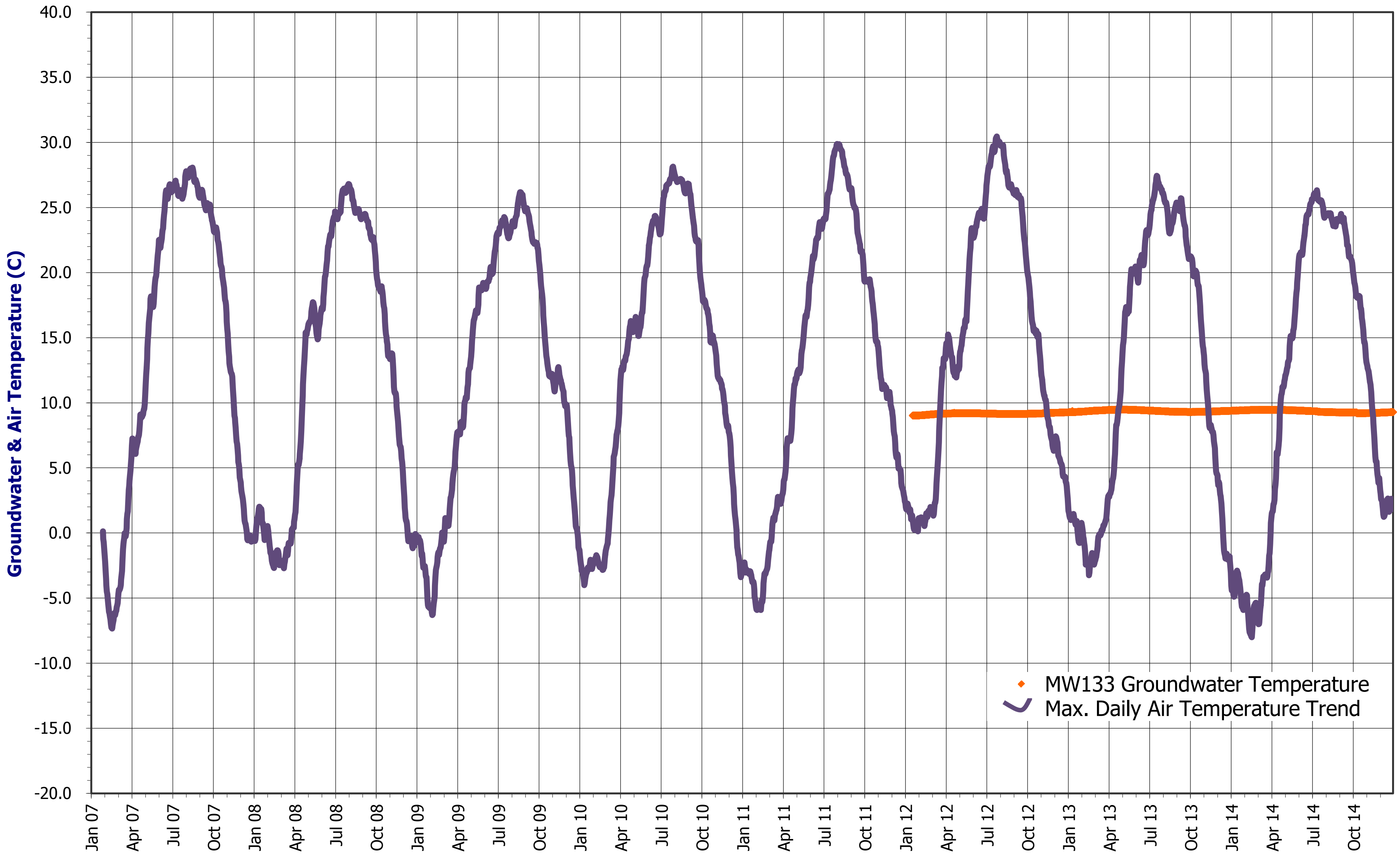
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Perimeter** **Graph H 11**

Groundwater & Maximum Daily Air Temperature - MW133 (January 12 to December 14)



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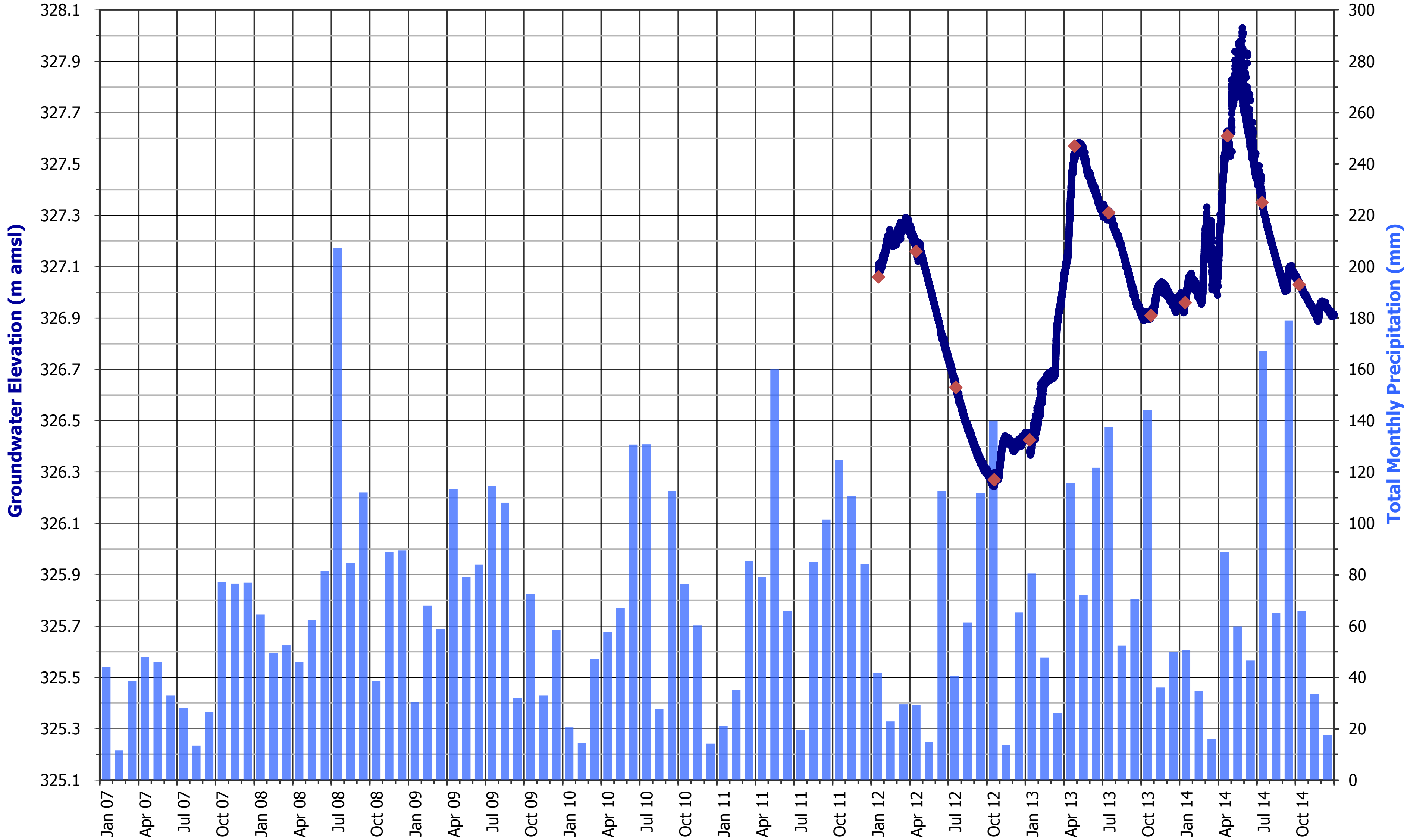
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Perimeter** **Graph H 11a**

Groundwater Elevation & Precipitation - MW134 (January 12 to December 14)



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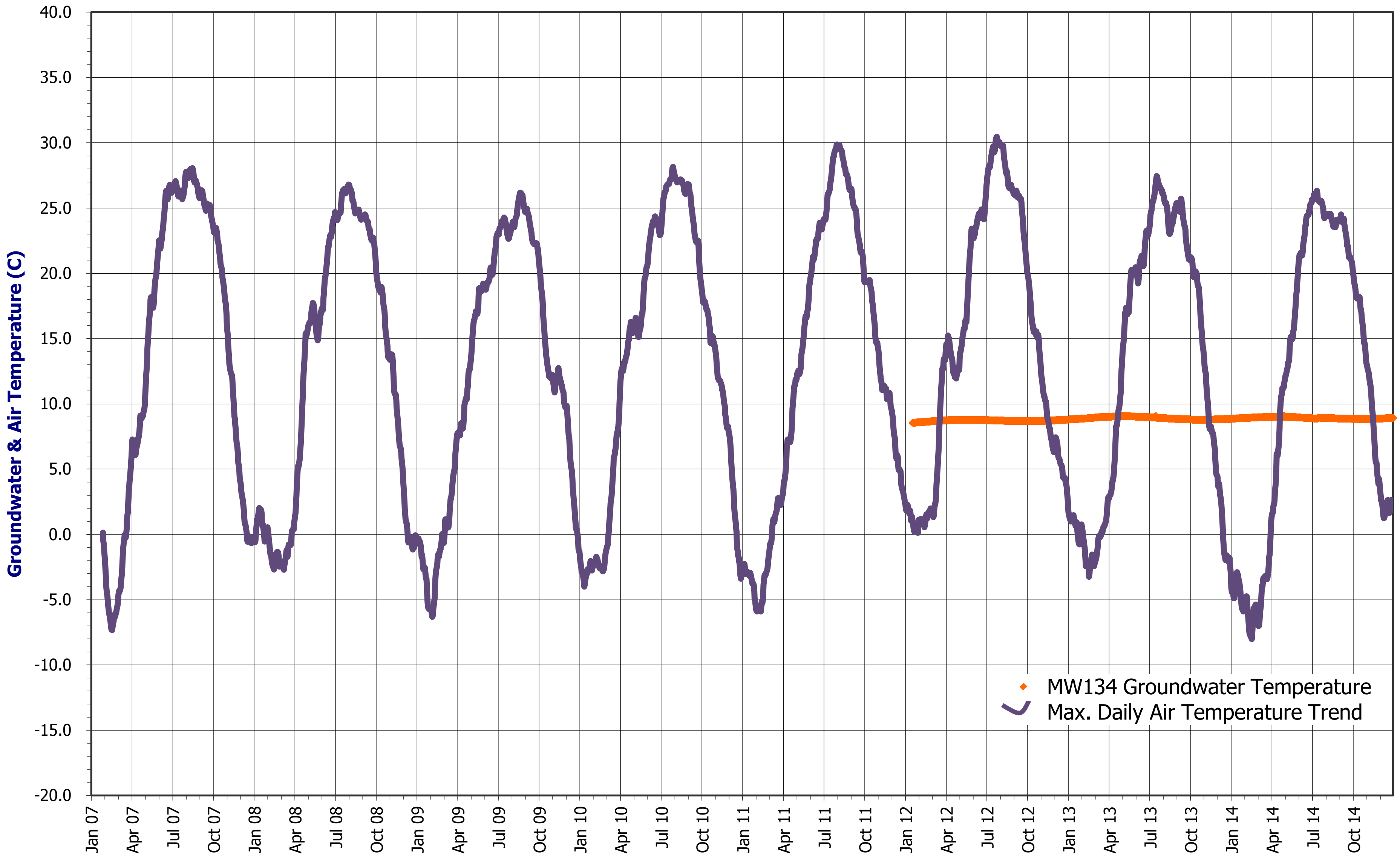
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Perimeter** **Graph H 12**

Groundwater & Maximum Daily Air Temperature - MW134 (January 12 to December 14)



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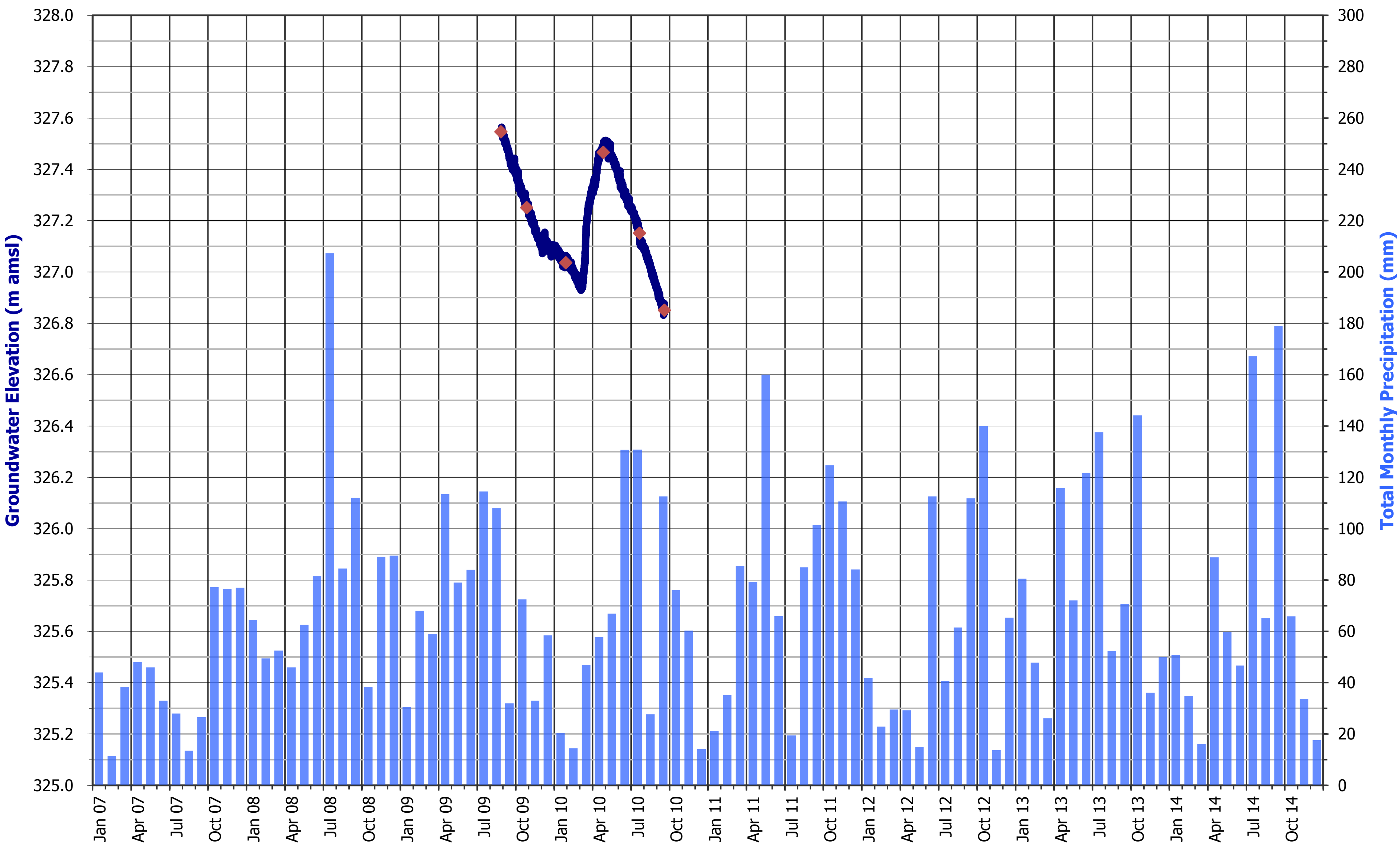
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Perimeter** **Graph H 12a**

Groundwater Elevation & Precipitation - MW110 (August 09 to September 10) Abandoned 2010



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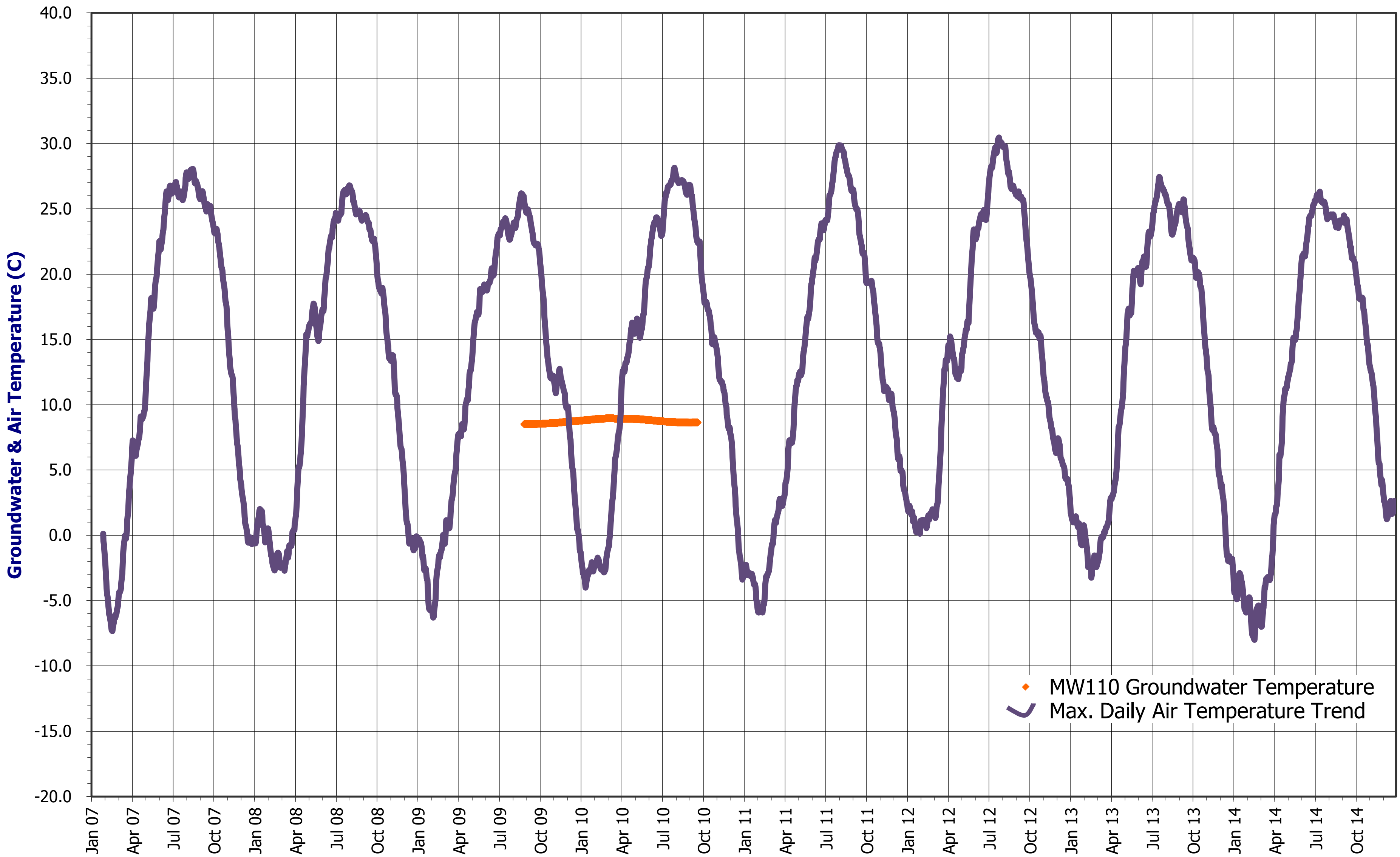
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Perimeter** **Graph H 13**

Groundwater & Maximum Daily Air Temperature - MW110 (August 09 to September 10) Abandoned 2010



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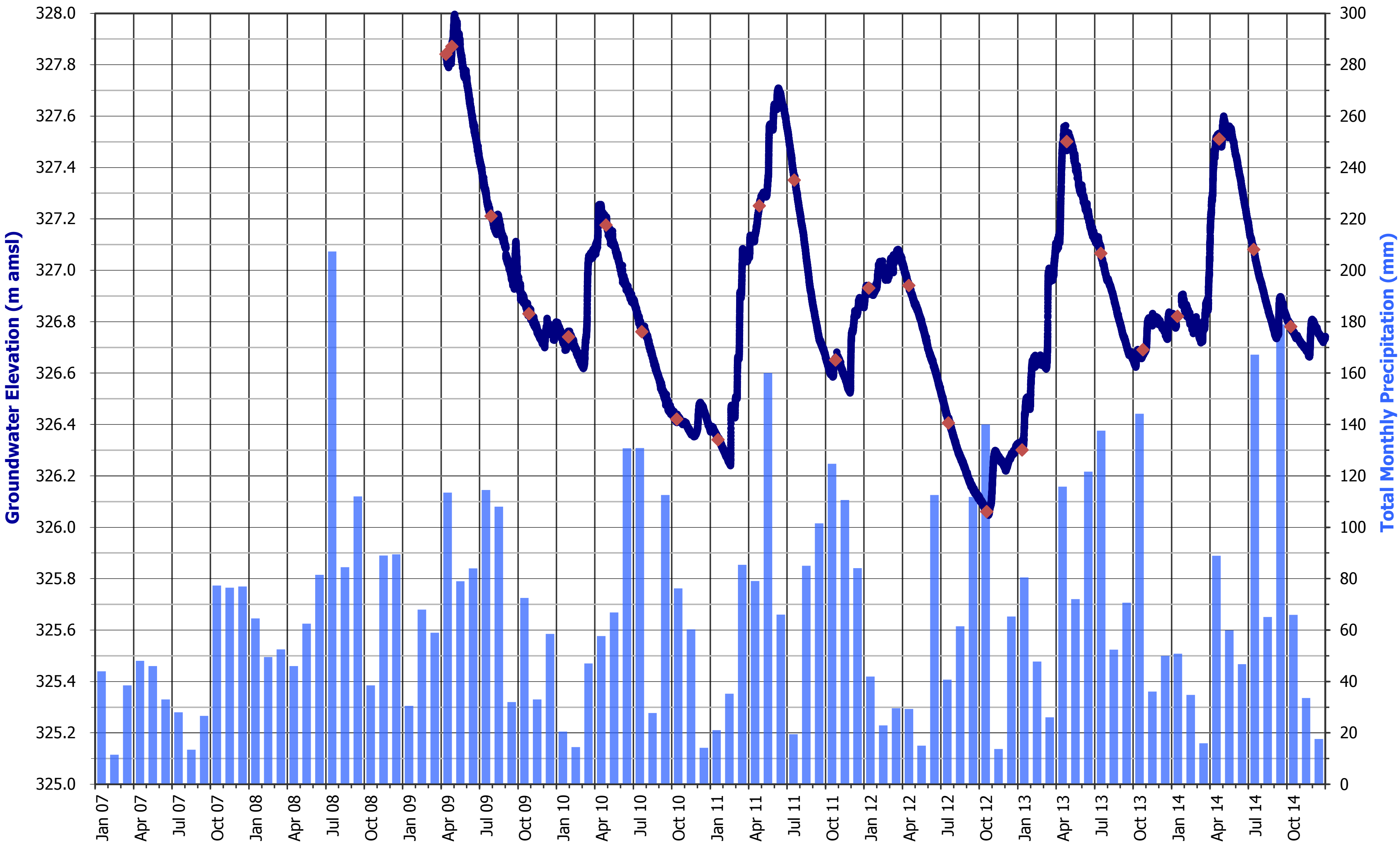
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 2 - Perimeter** **Graph H 13a**

Groundwater Elevation & Precipitation - MW109 (April 09 to December 14)



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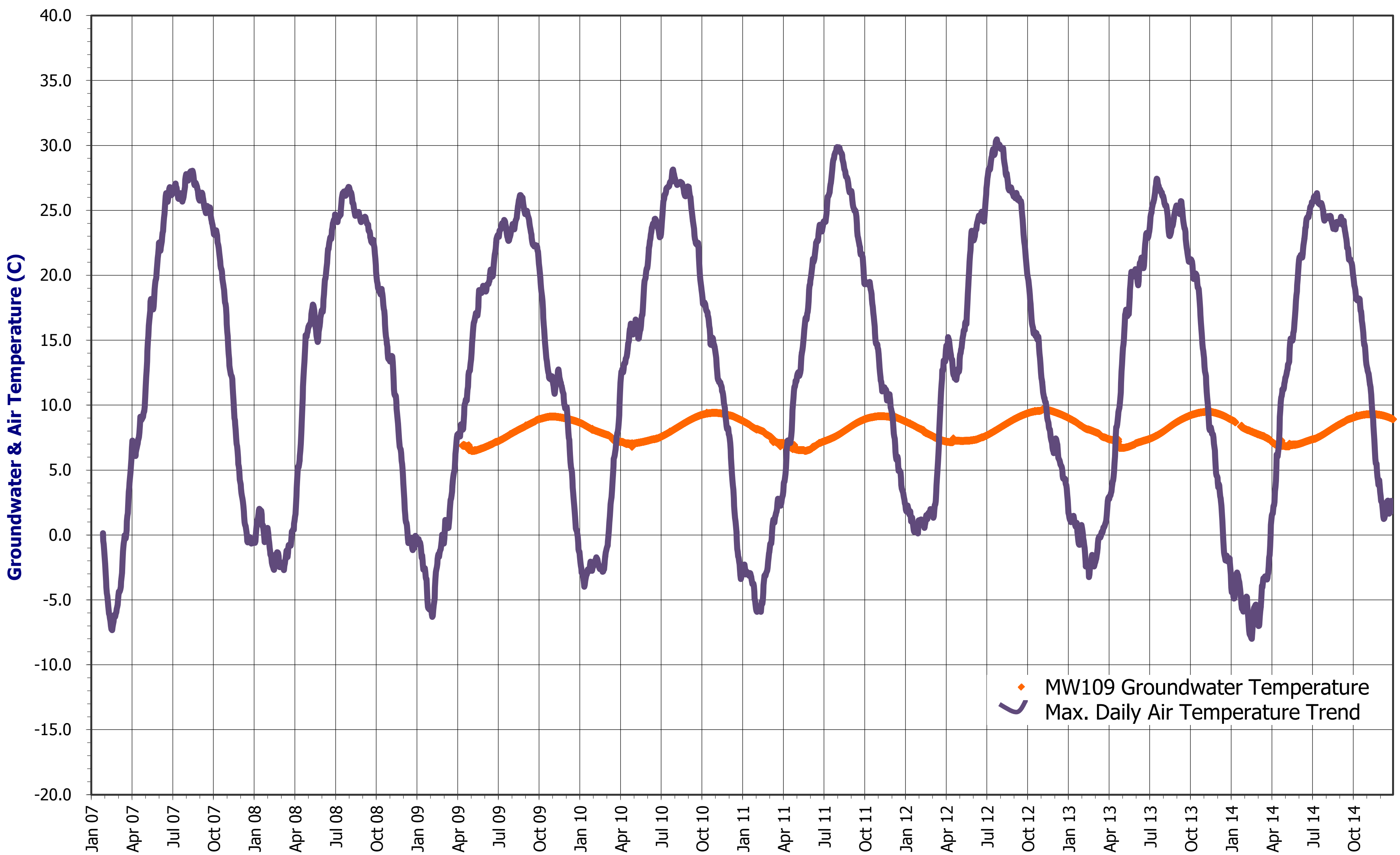
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 3 - Perimeter** **Graph H 14**

Groundwater & Maximum Daily Air Temperature - MW109 (April 09 to December 14)



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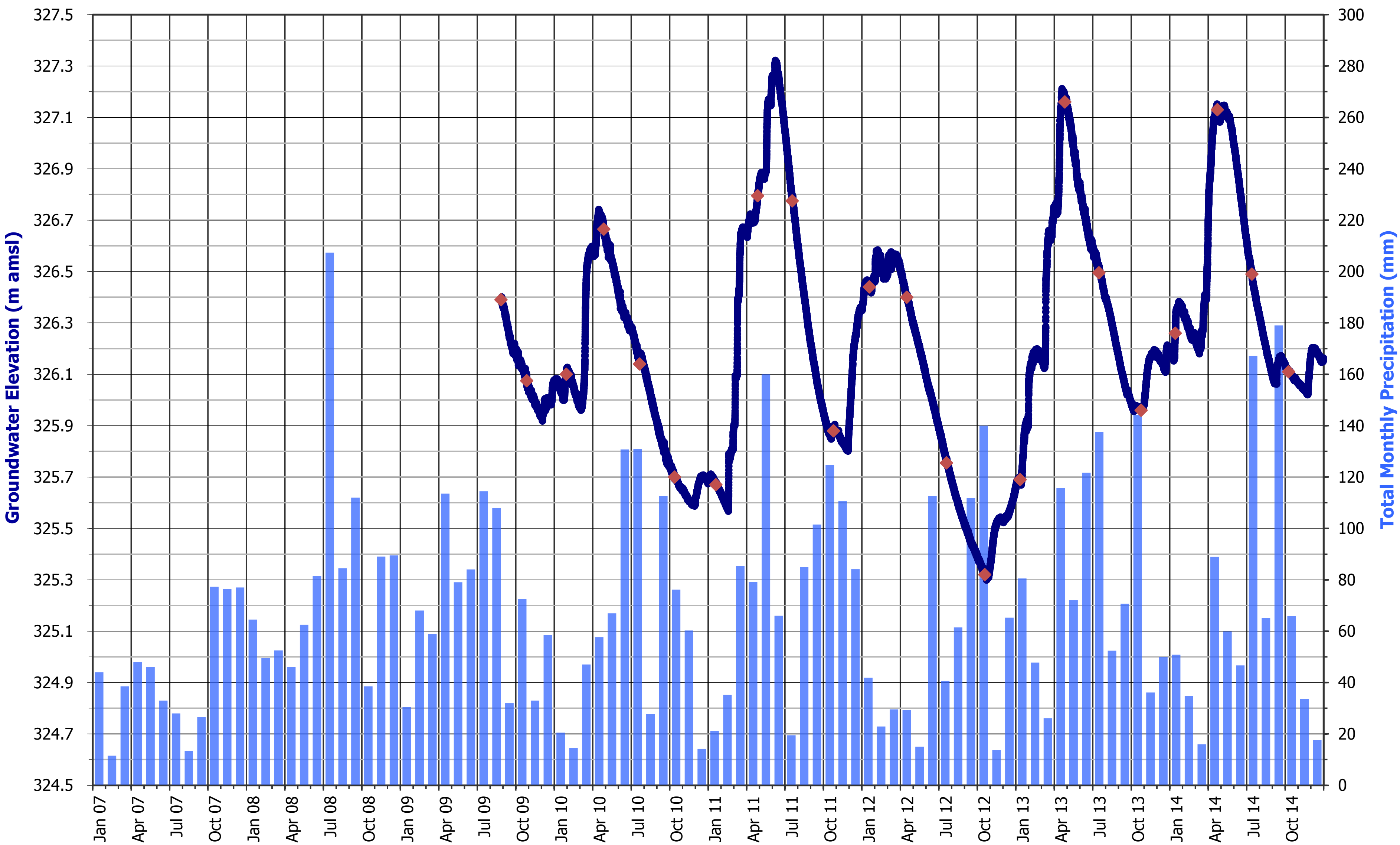
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 3 - Perimeter** **Graph H 14a**

Groundwater Elevation & Precipitation - MW004 (August 09 to December 14)



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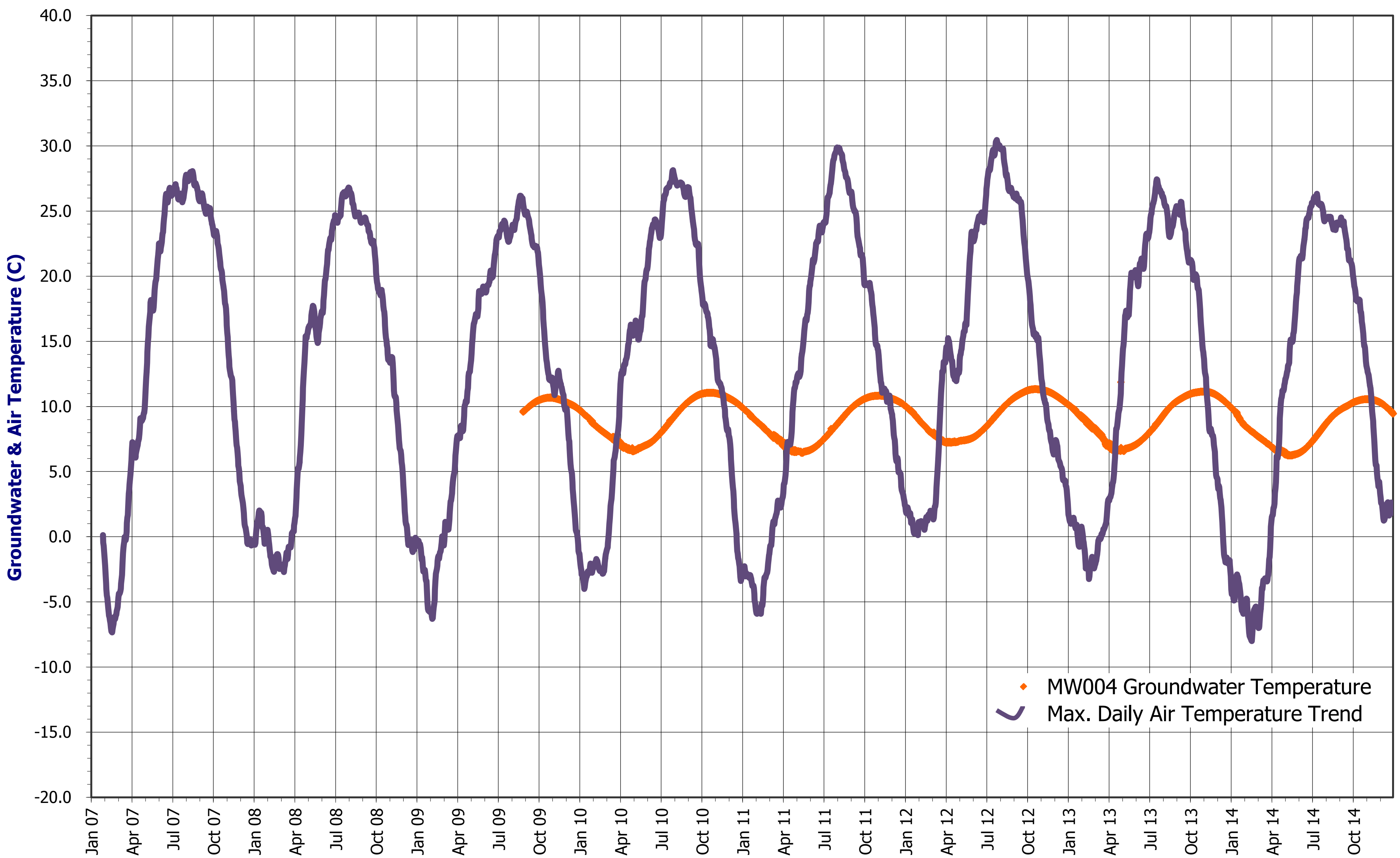
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 3 - Perimeter** **Graph H 15**

Groundwater & Maximum Daily Temperature - MW004 (August 09 to December 14)



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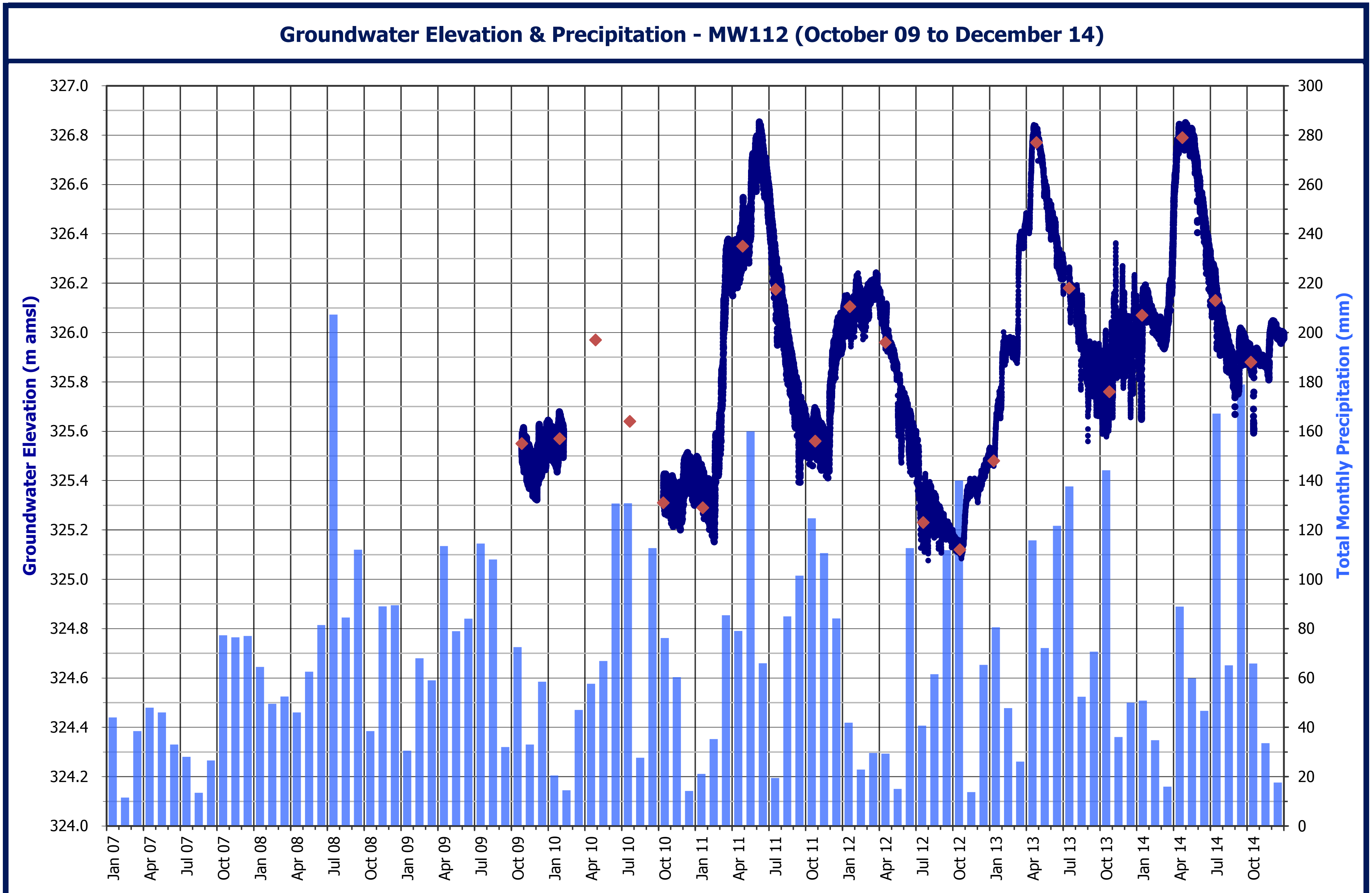
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 3 - Perimeter** **Graph H 15a**



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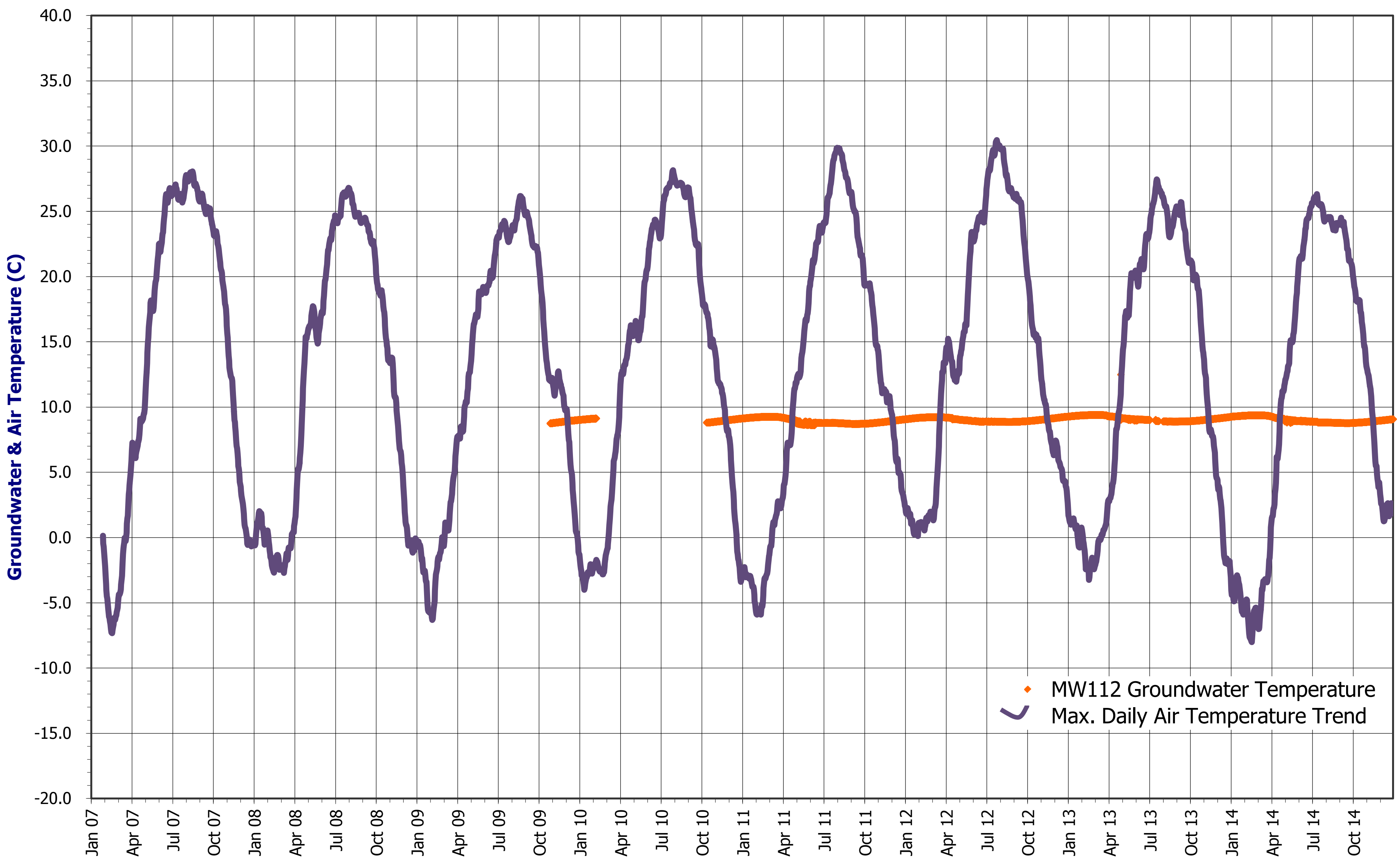
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 3 - Perimeter Graph H 16**

Groundwater & Maximum Daily Air Temperature - MW112 (October 09 to December 14)



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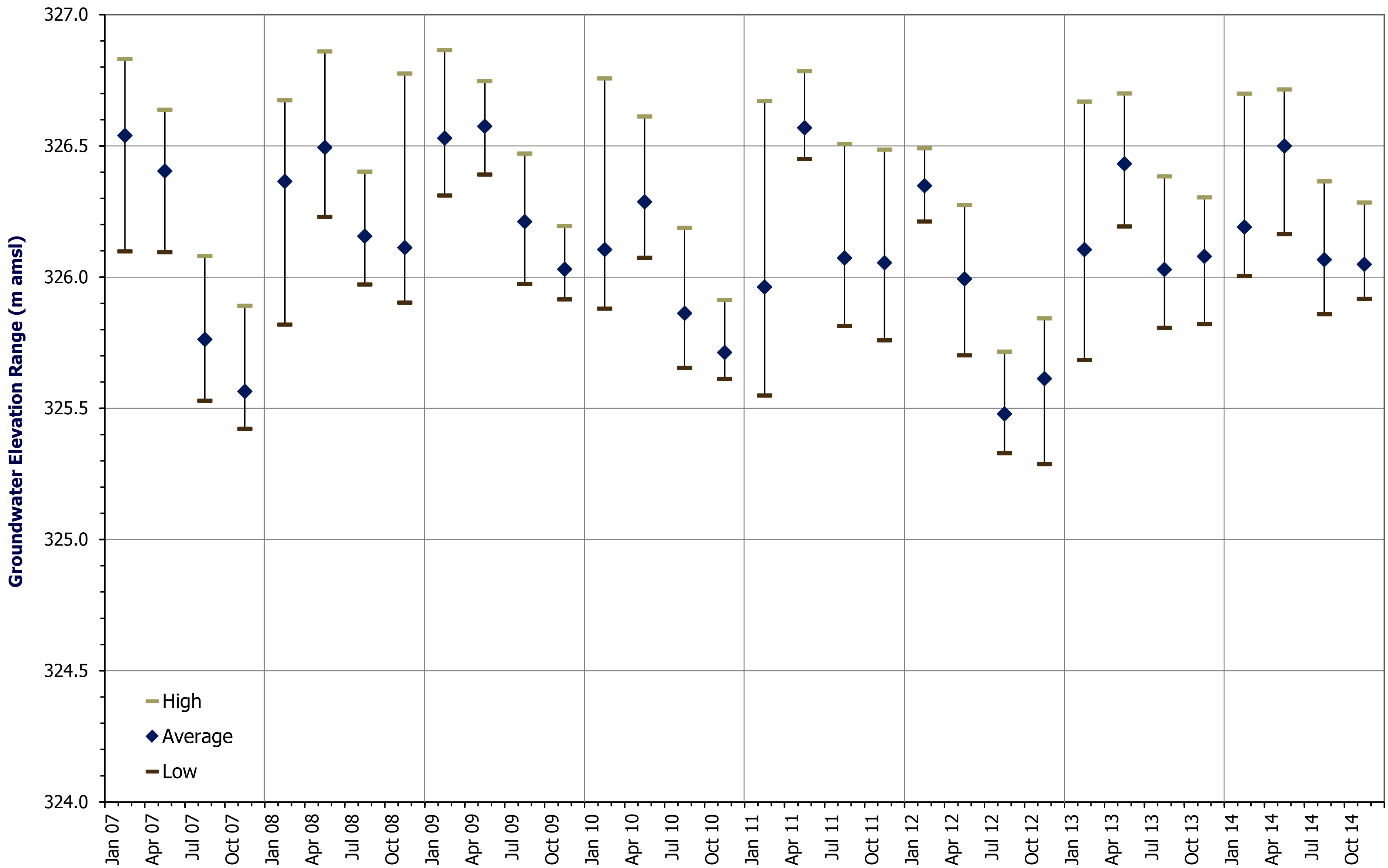
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Phase 3 - Perimeter** **Graph H 16a**

Appendix I

Quarterly Groundwater Elevation Range
2007 – 2014

Quarterly Groundwater Elevation Range - MW003



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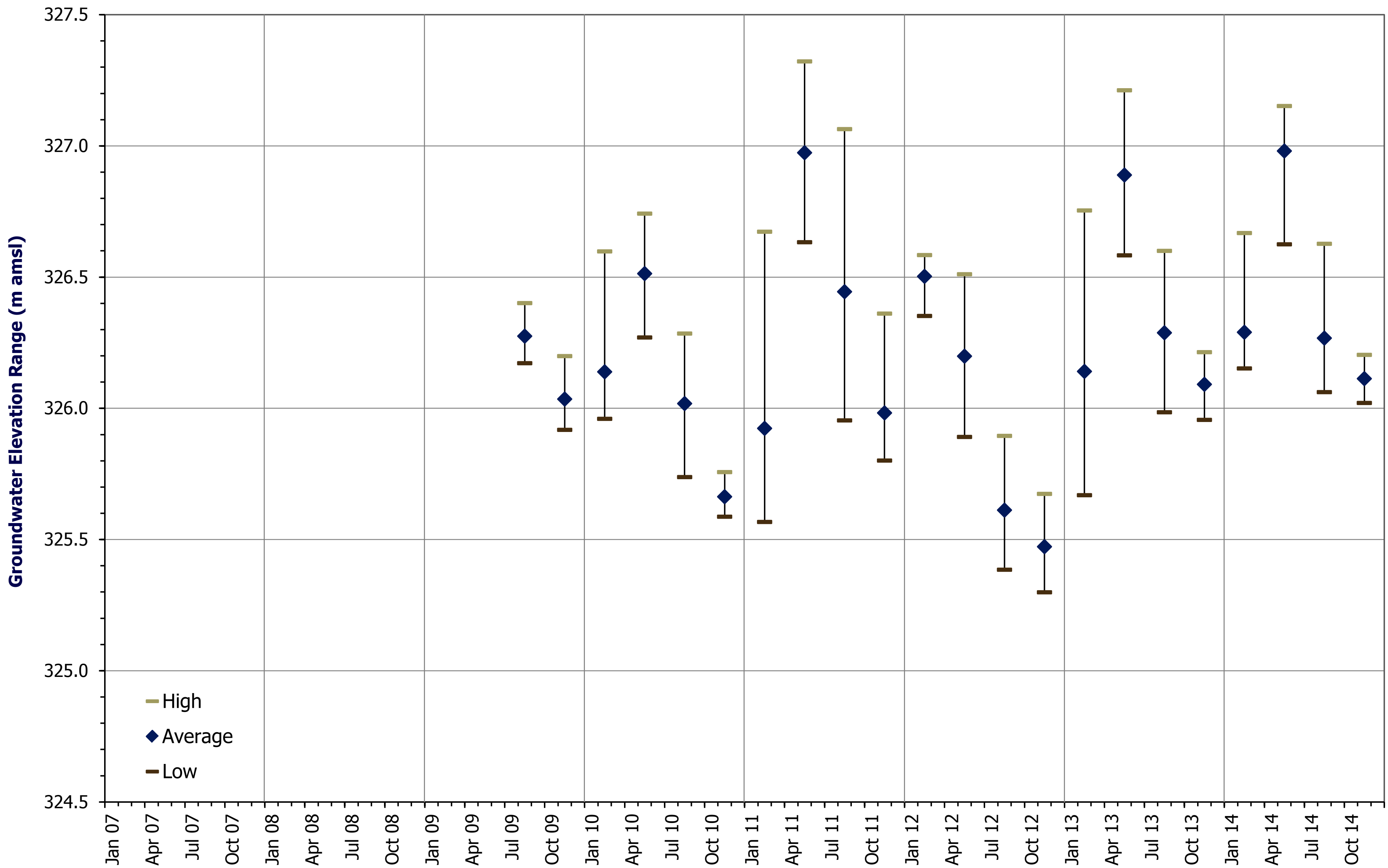
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014

Graph I-1

Quarterly Groundwater Elevation Range - MW004



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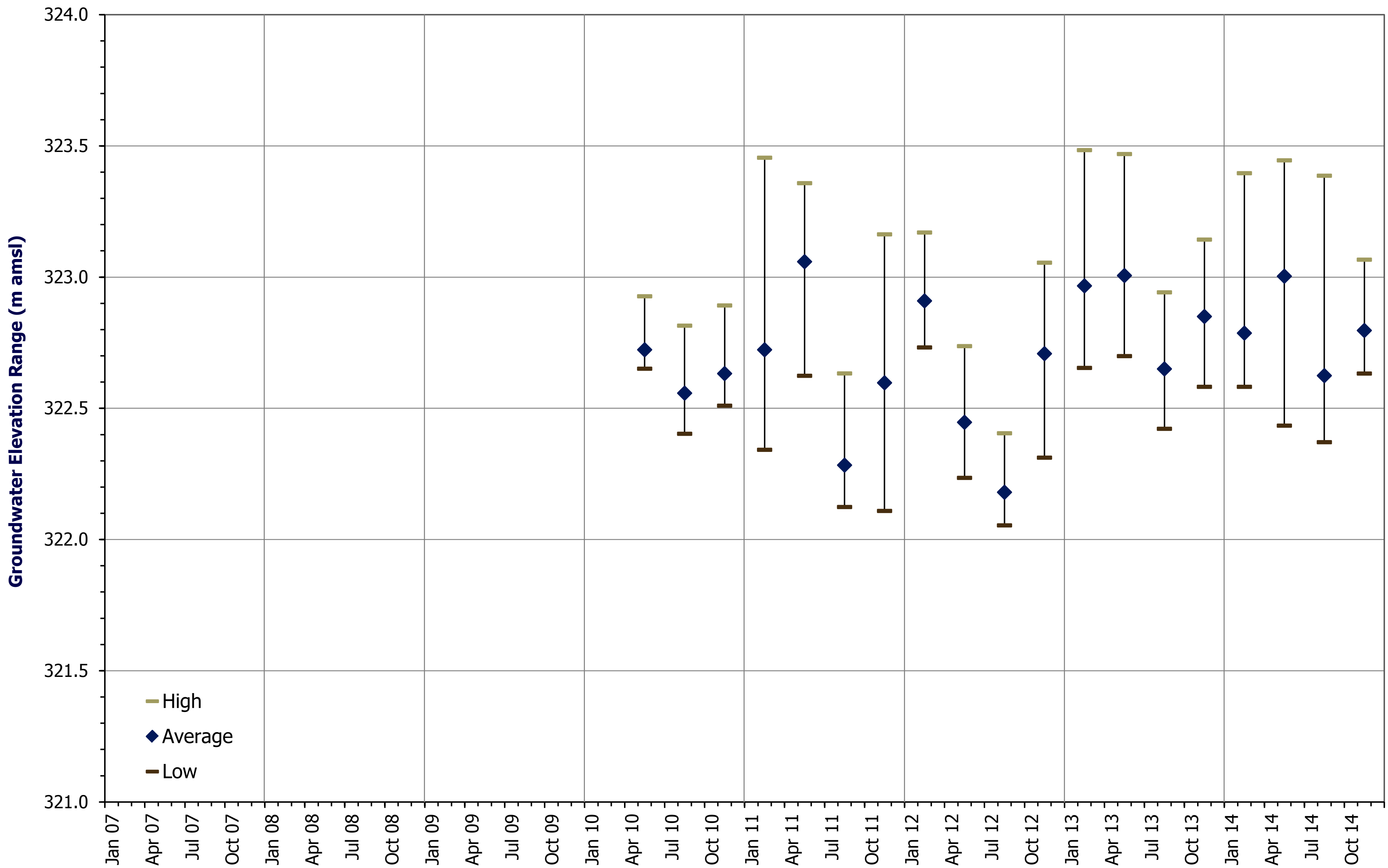
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014

Graph I-2

Quarterly Groundwater Elevation Range - MW103



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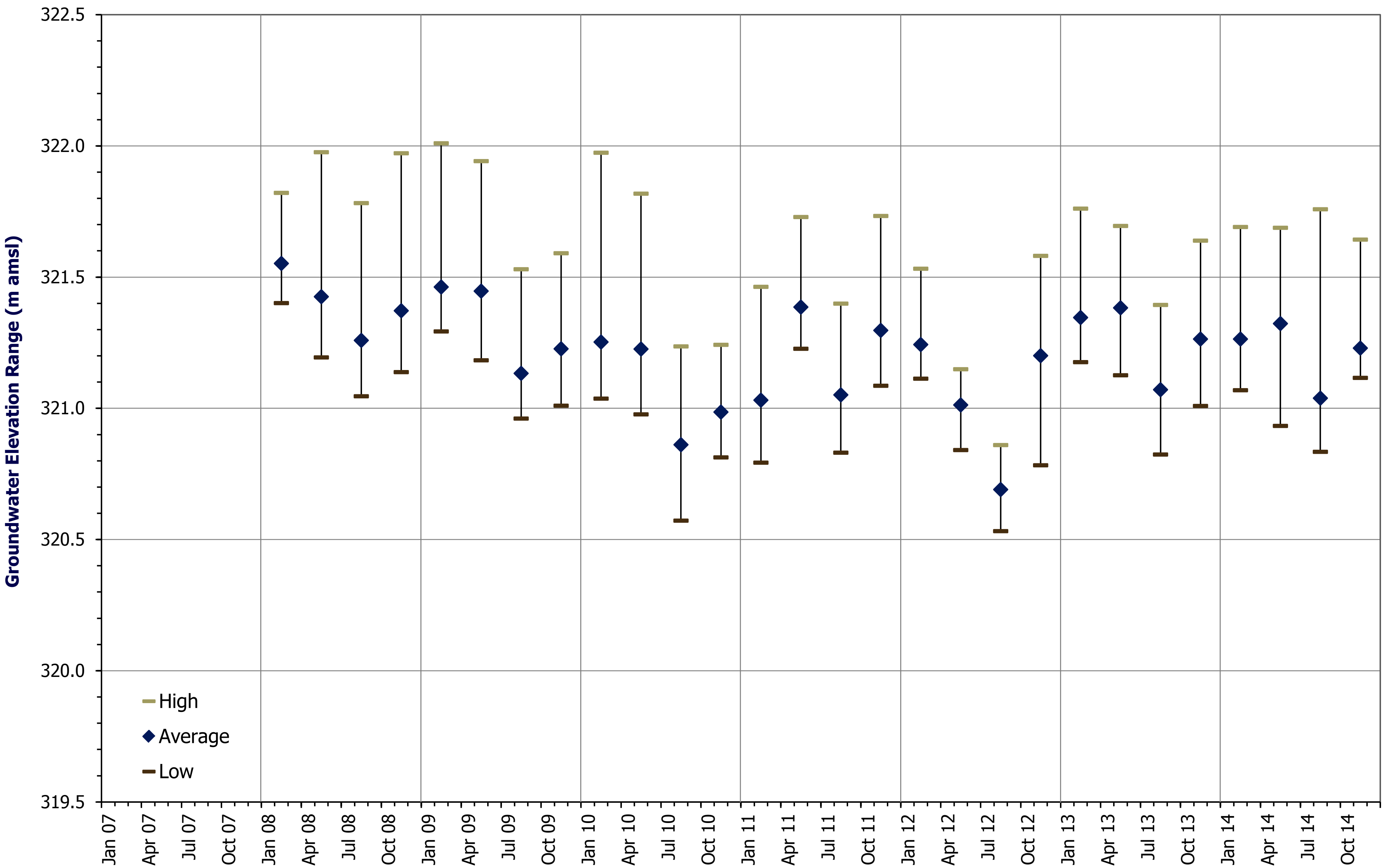
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014

Graph I-3

Quarterly Groundwater Elevation Range - MW104



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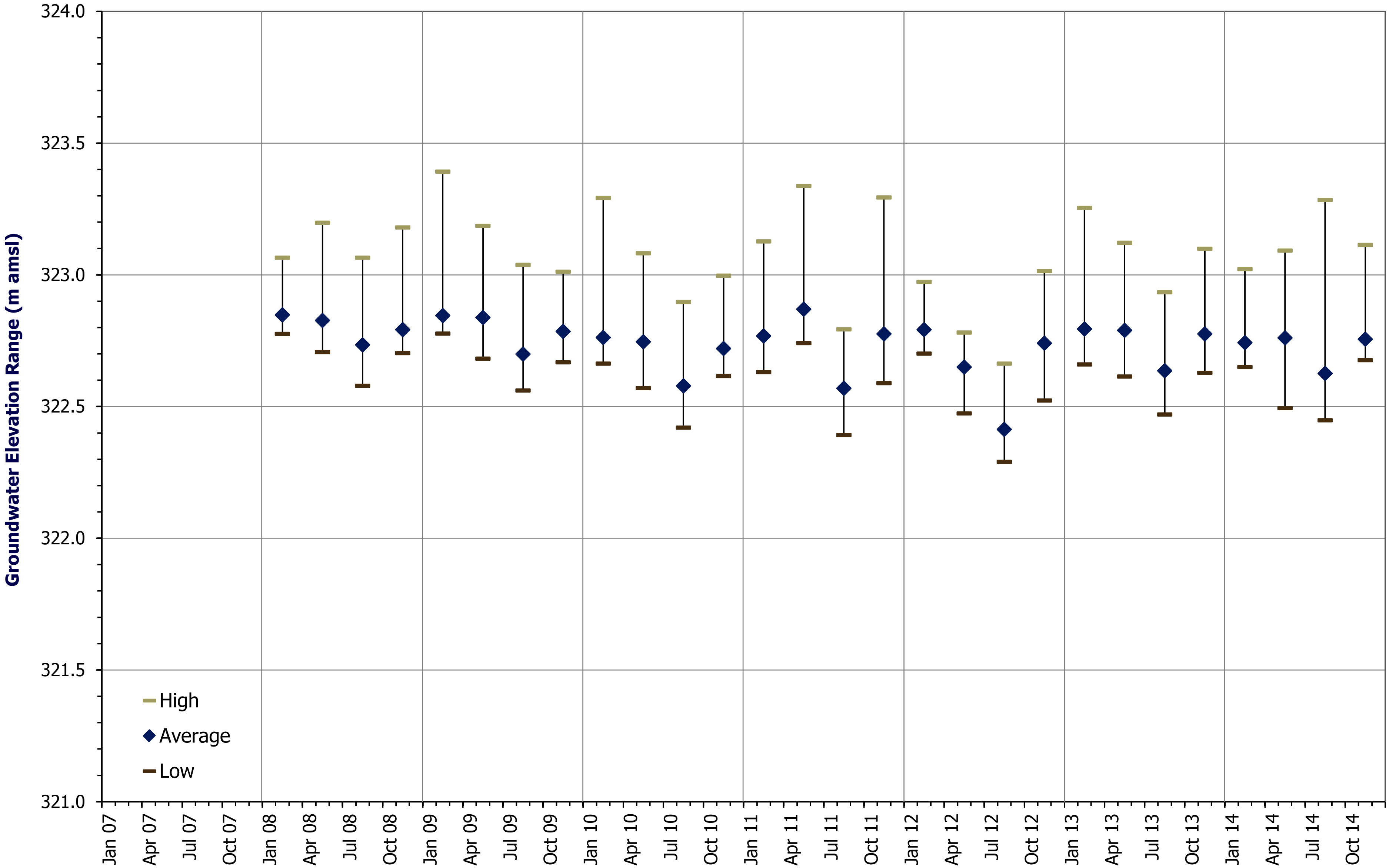
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Graph I-4**

Quarterly Groundwater Elevation Range - MW105



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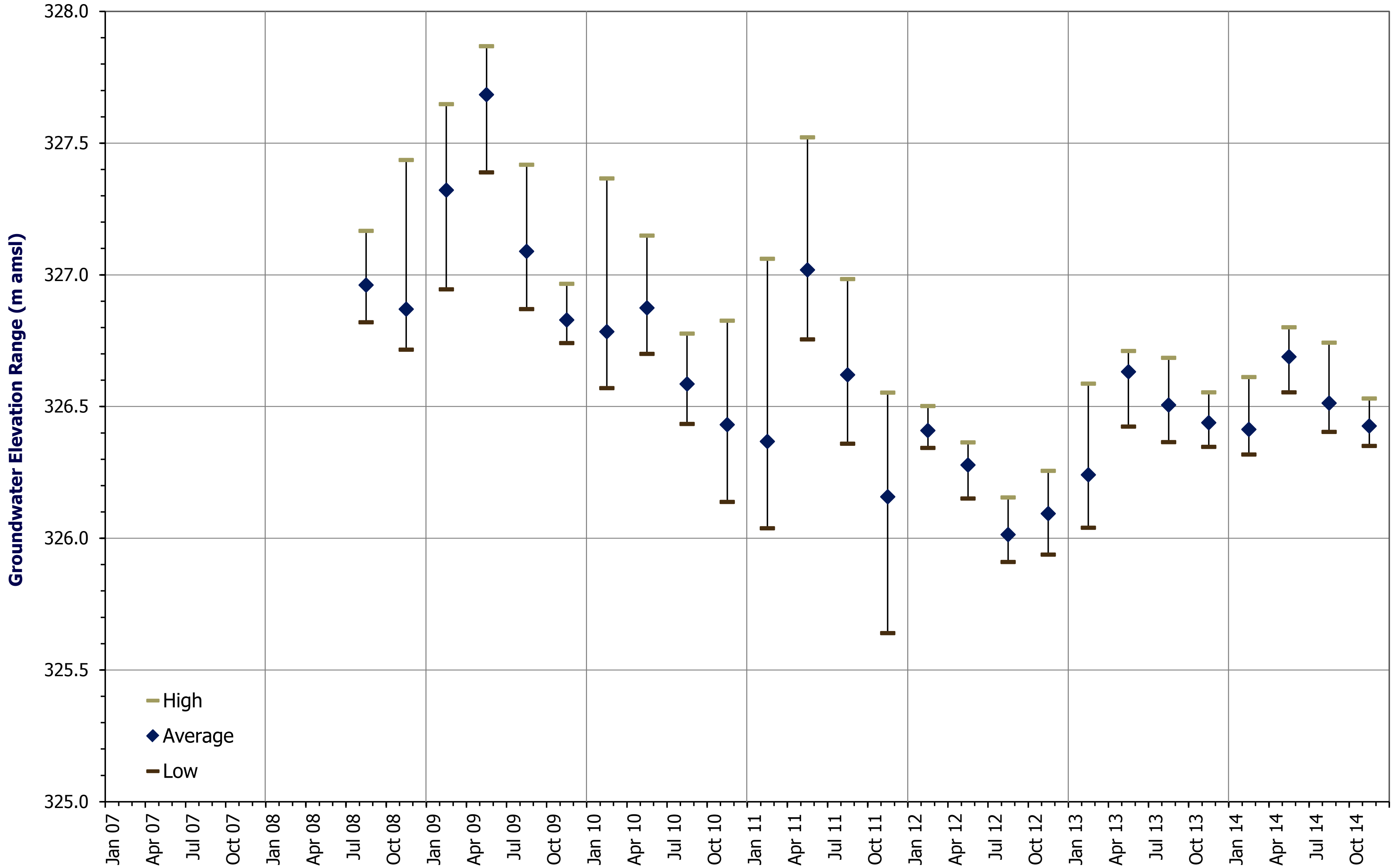
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014

Graph I-5

Quarterly Groundwater Elevation Range - MW107



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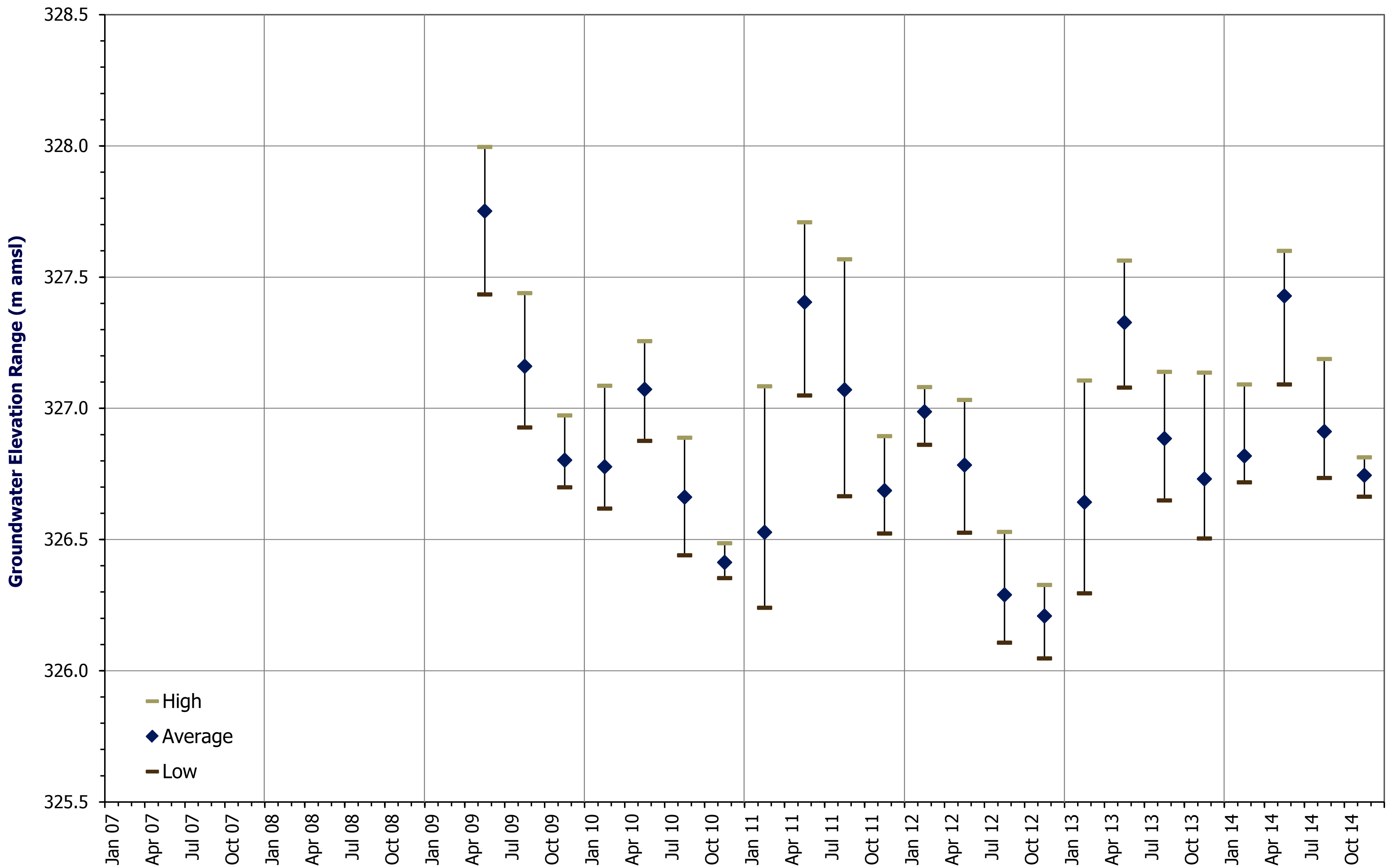
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014

Graph I-6

Quarterly Groundwater Elevation Range - MW109



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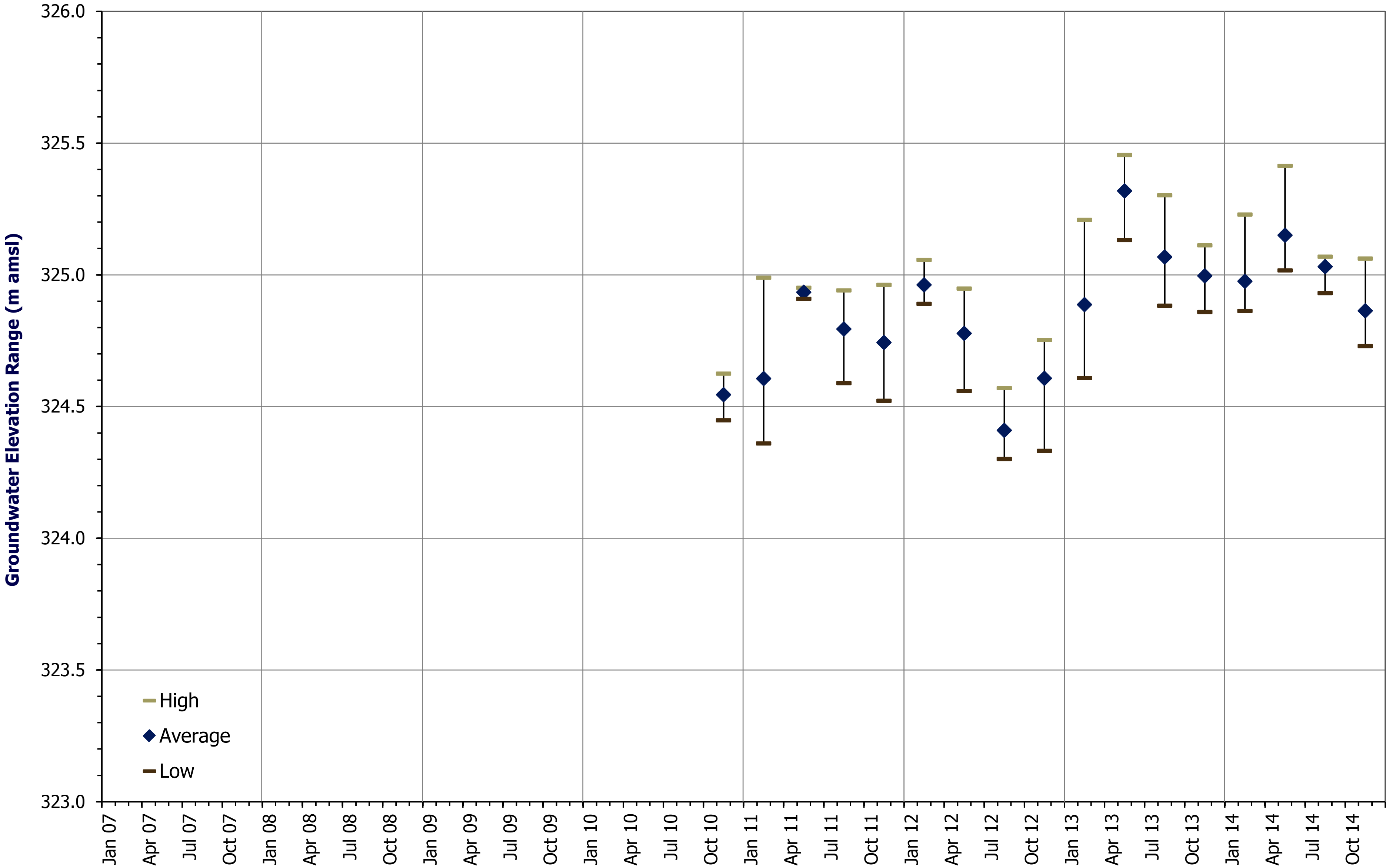
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014

Graph I-7

Quarterly Groundwater Elevation Range - MW111



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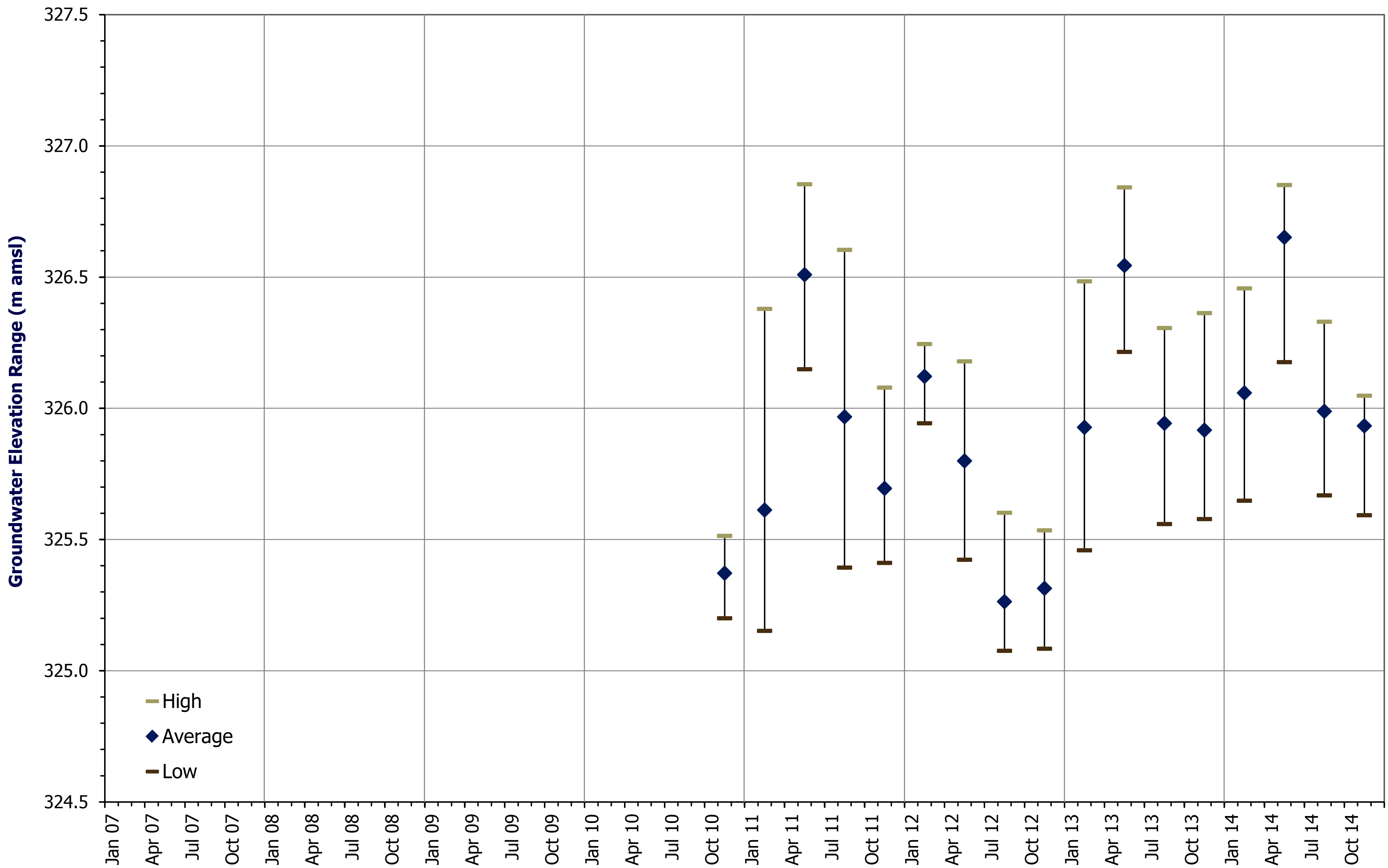
Hanlon Creek Business Park - Groundwater Monitoring Program

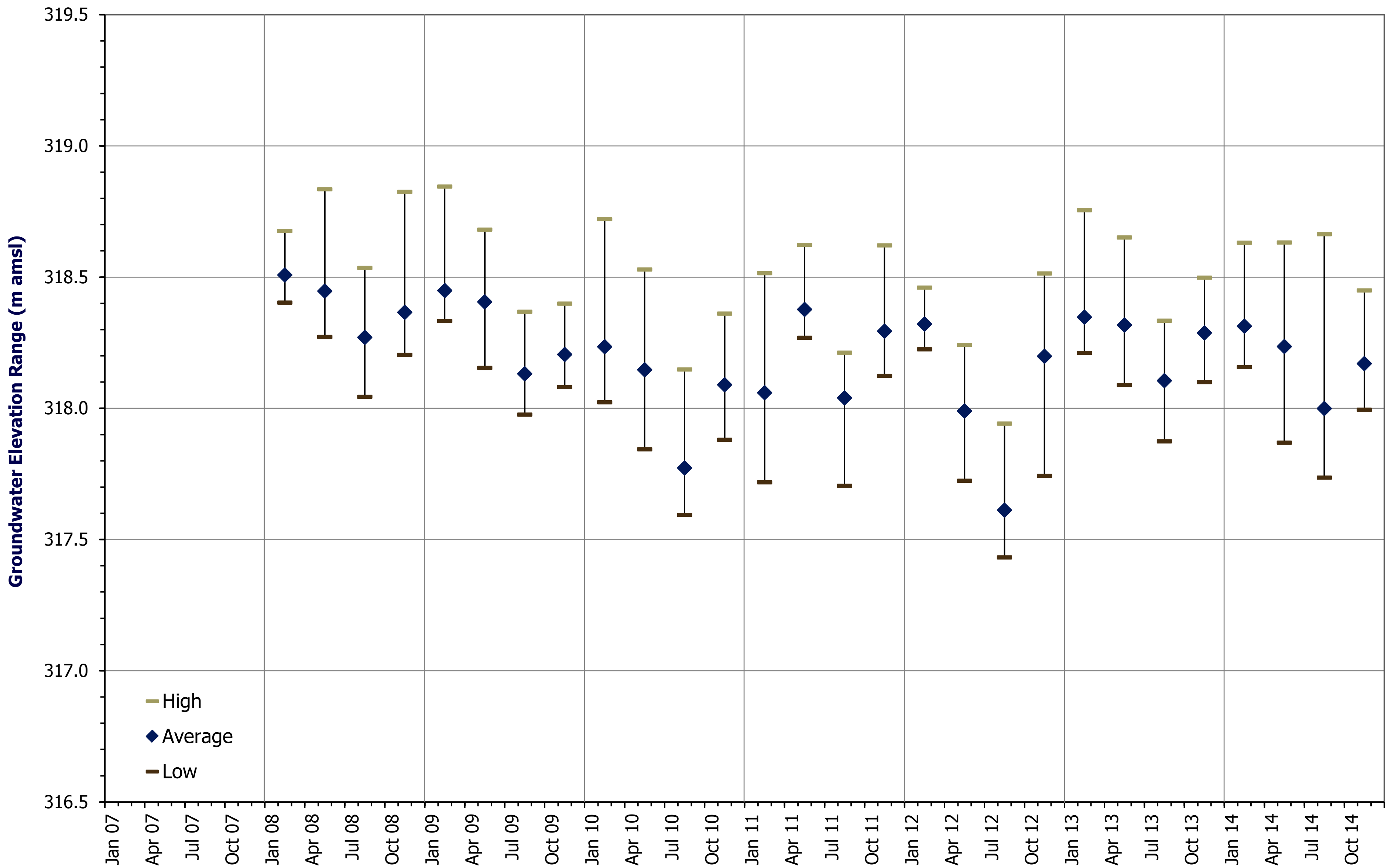
December 2014

Graph I-8

Quarterly Groundwater Elevation Range - MW112



Quarterly Groundwater Elevation Range - MW116A



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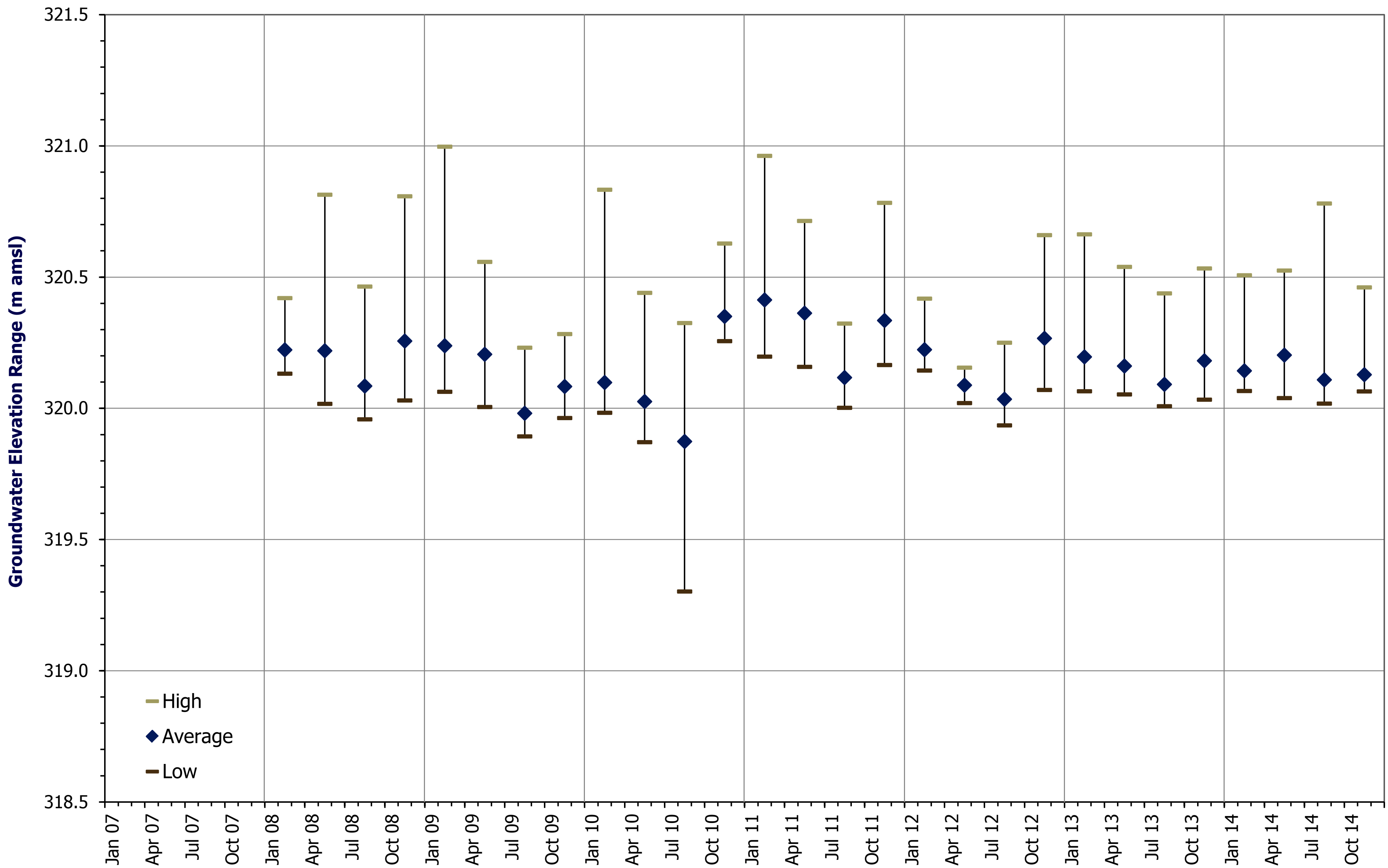
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014

Graph I-10

Quarterly Groundwater Elevation Range - MW117A



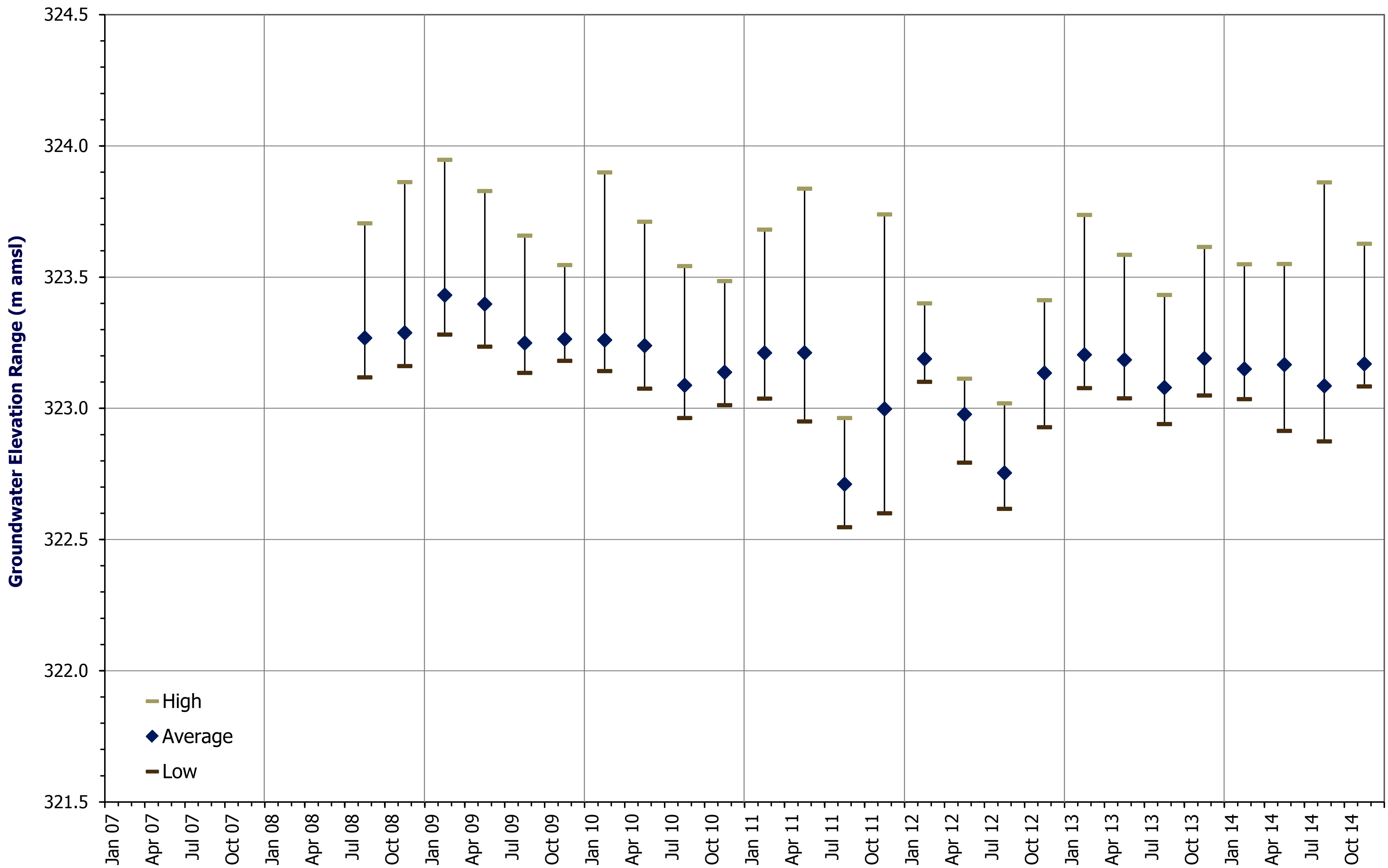
Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014

Graph I-11

Quarterly Groundwater Elevation Range - MW118A



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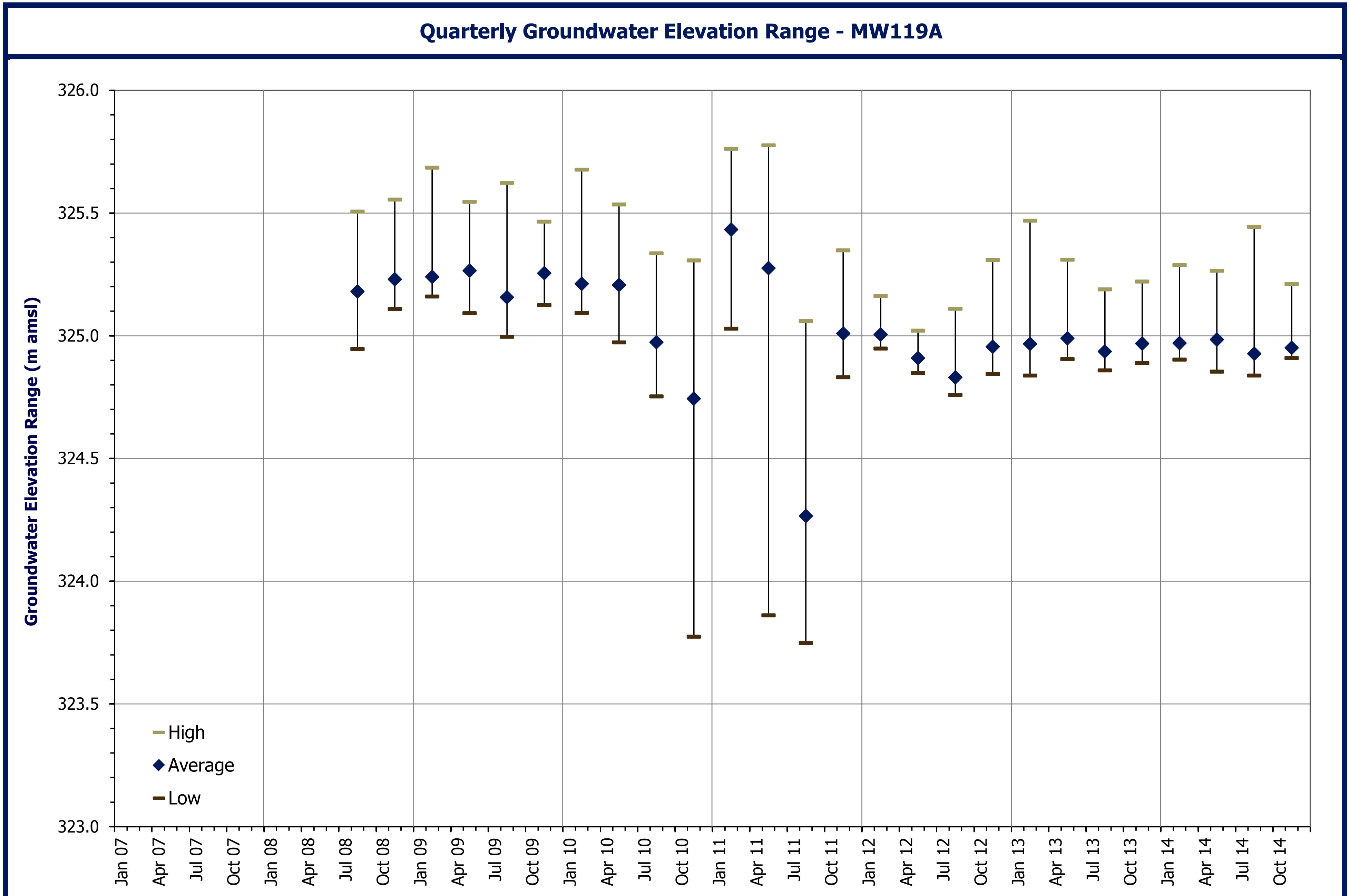
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014

Graph I-12



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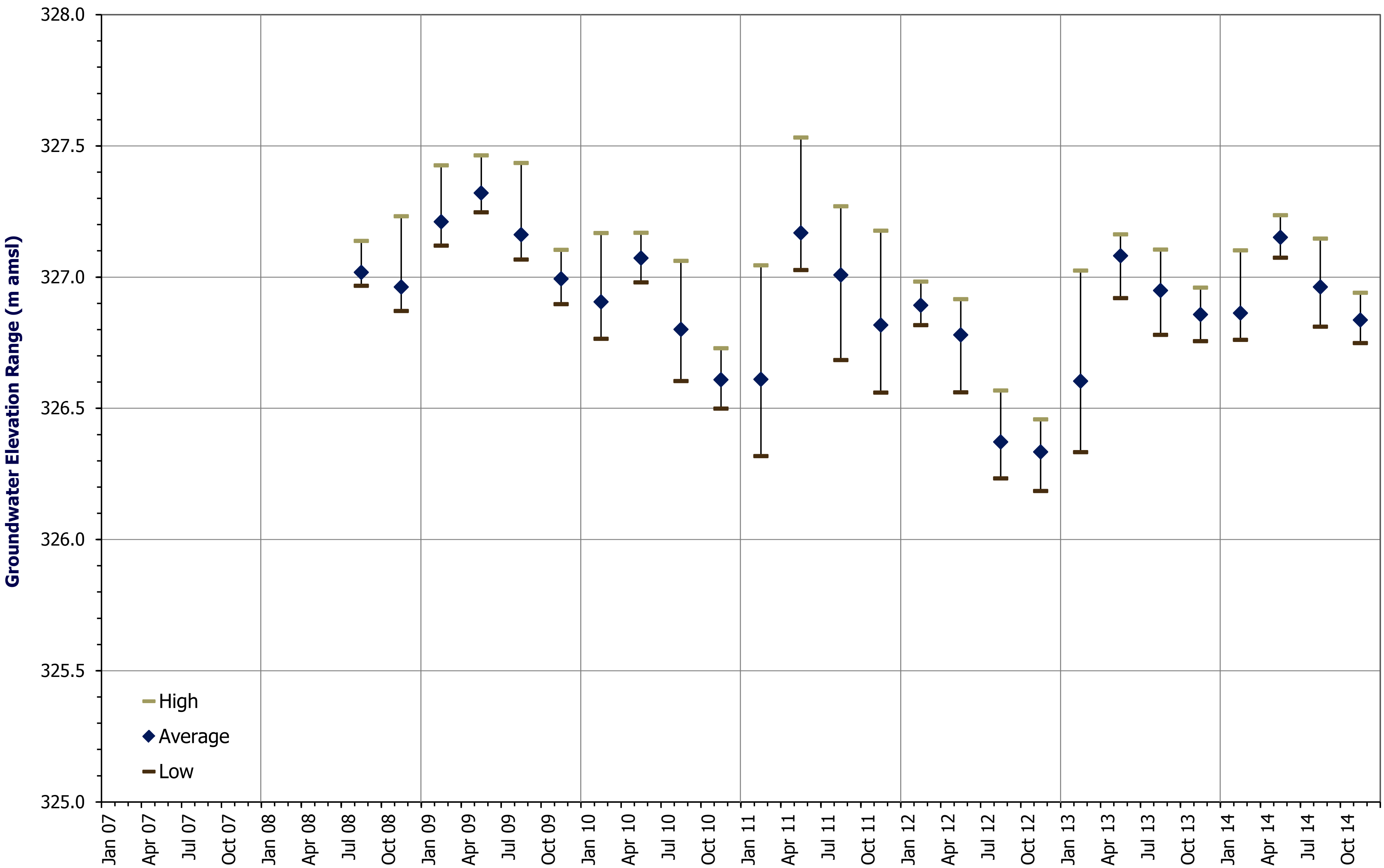
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014

Graph I-13

Quarterly Groundwater Elevation Range - MW121A



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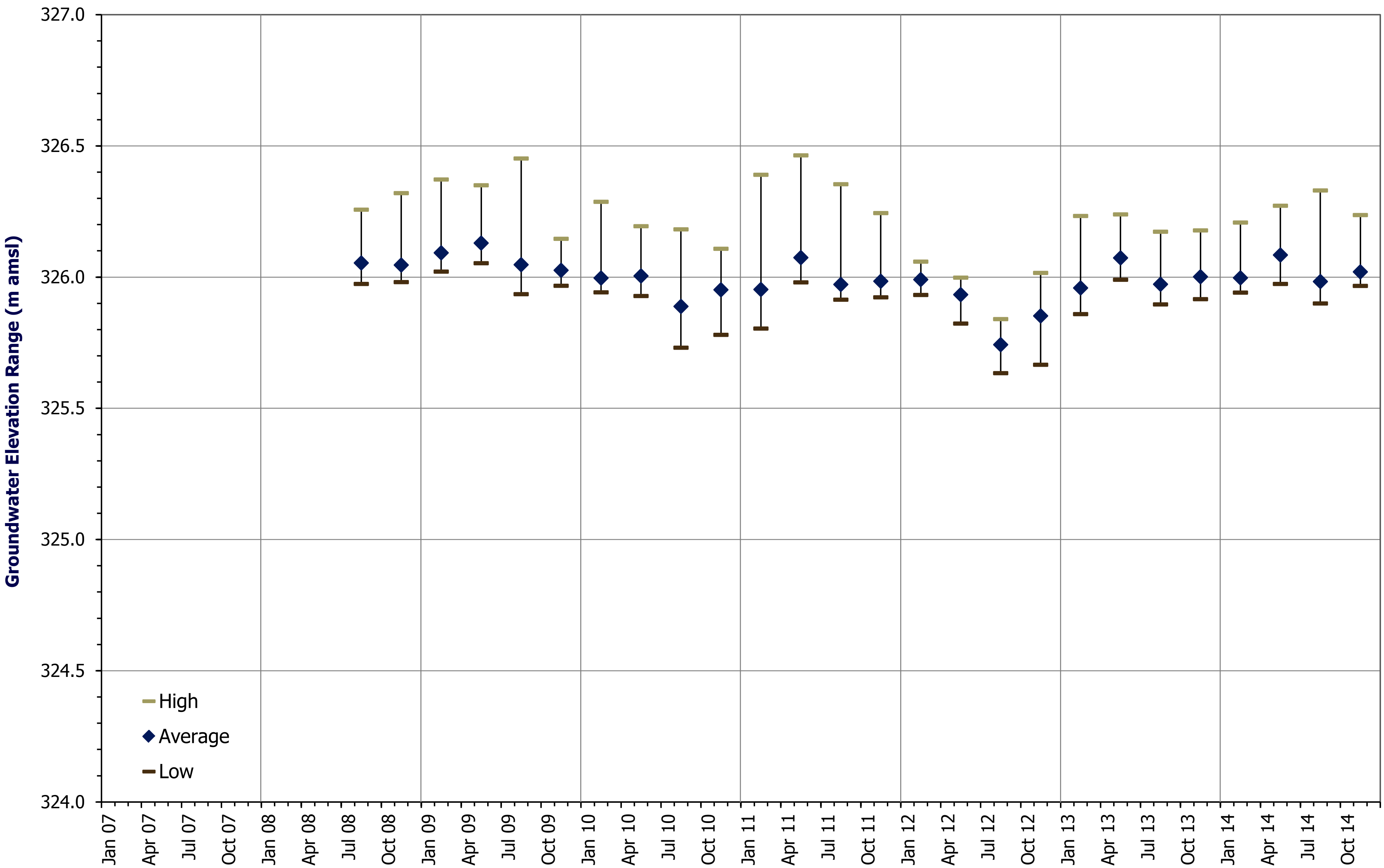
Hanlon Creek Business Park - Groundwater Monitoring Program

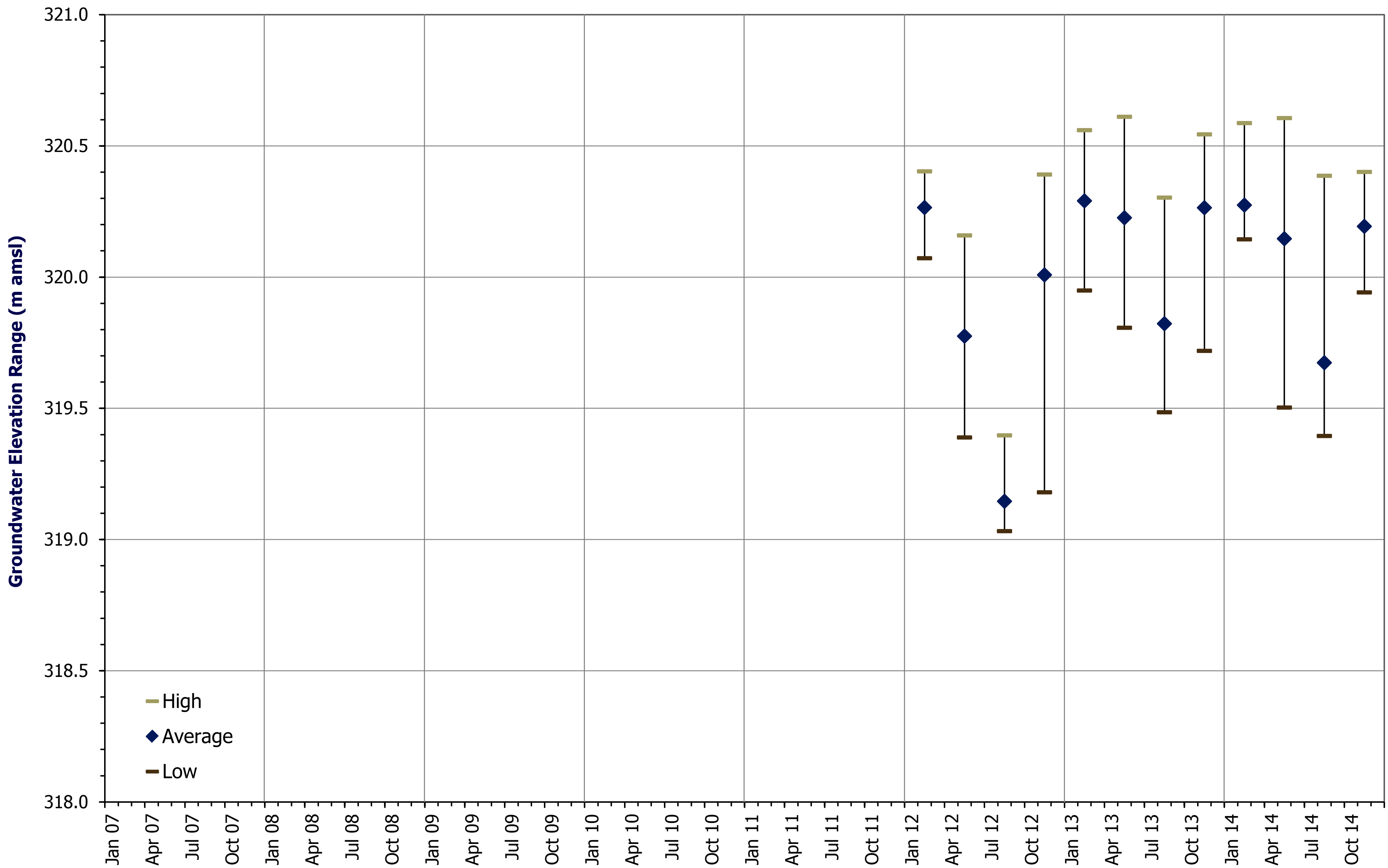
December 2014

Graph I-14

Quarterly Groundwater Elevation Range - MW122A



Quarterly Groundwater Elevation Range - MW124



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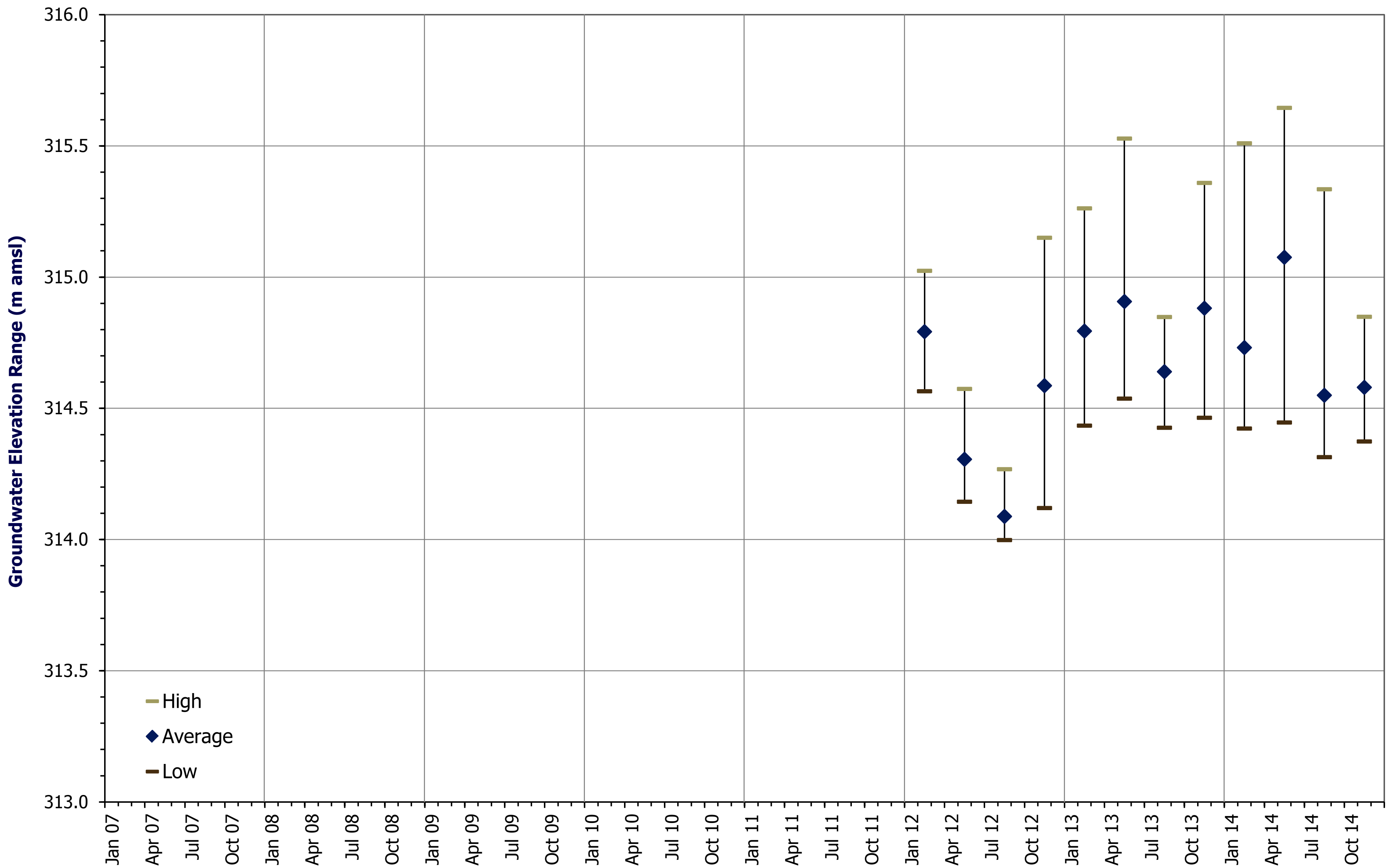
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014

Graph I-16

Quarterly Groundwater Elevation Range - MW125



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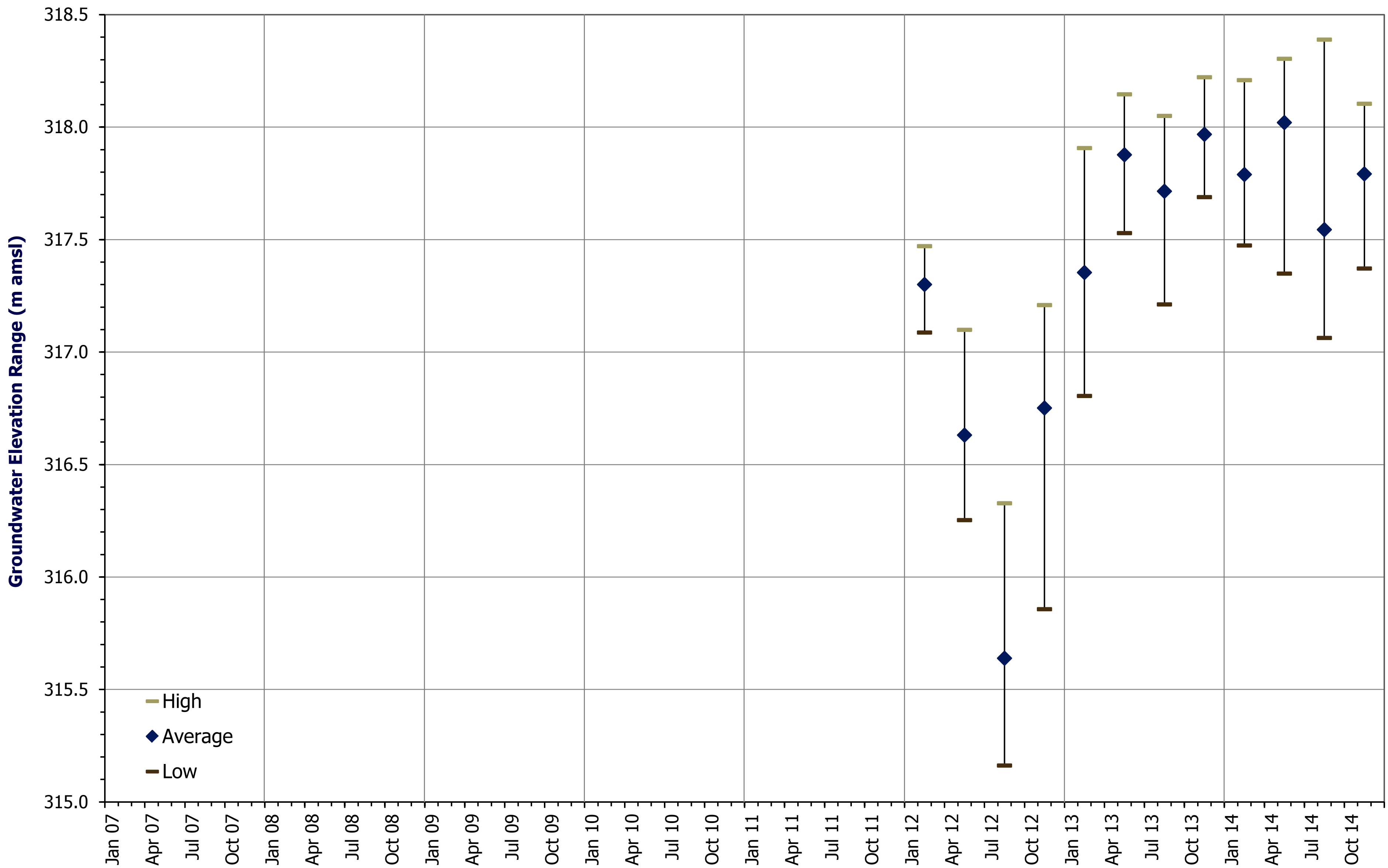
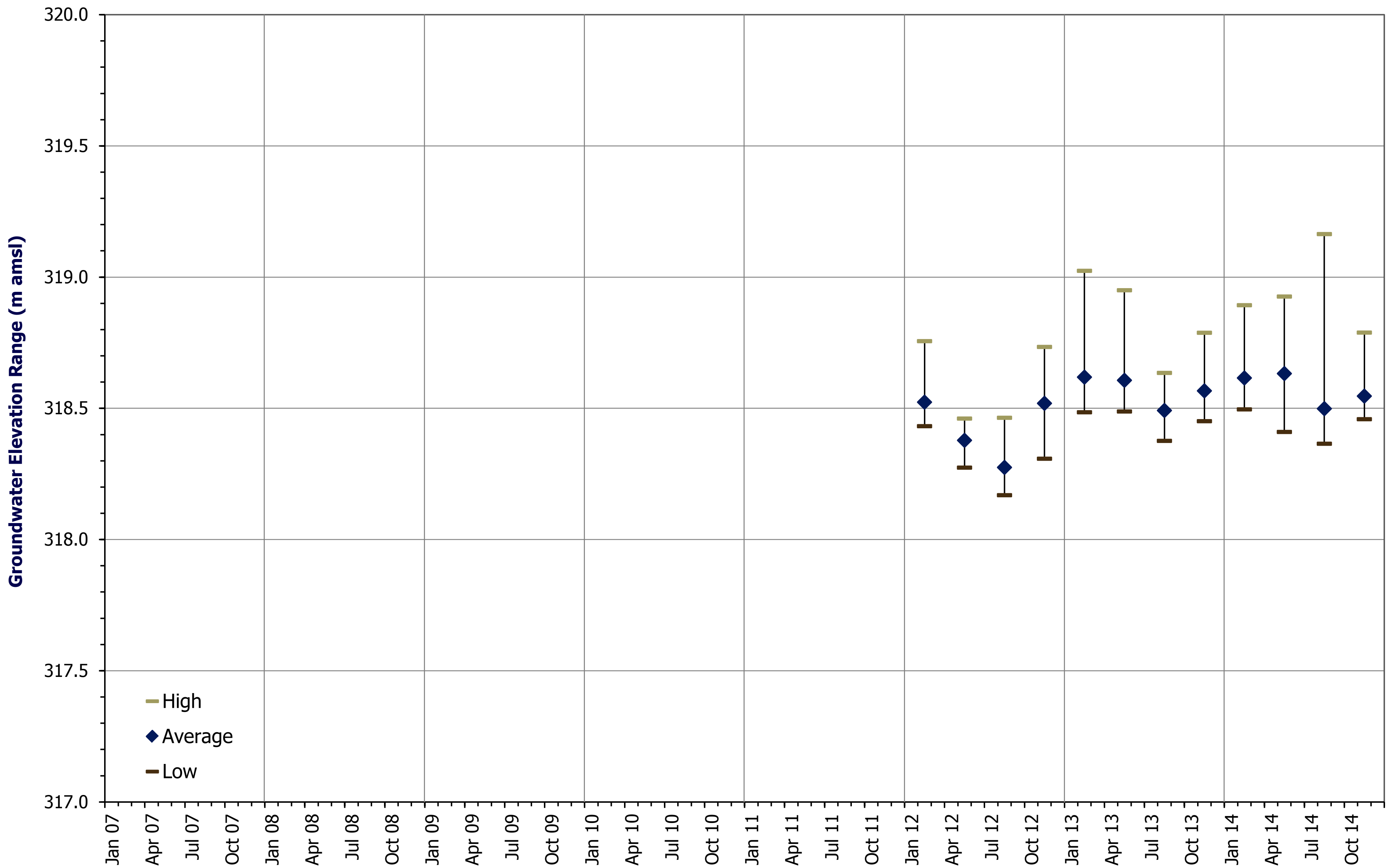
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Graph I-17**

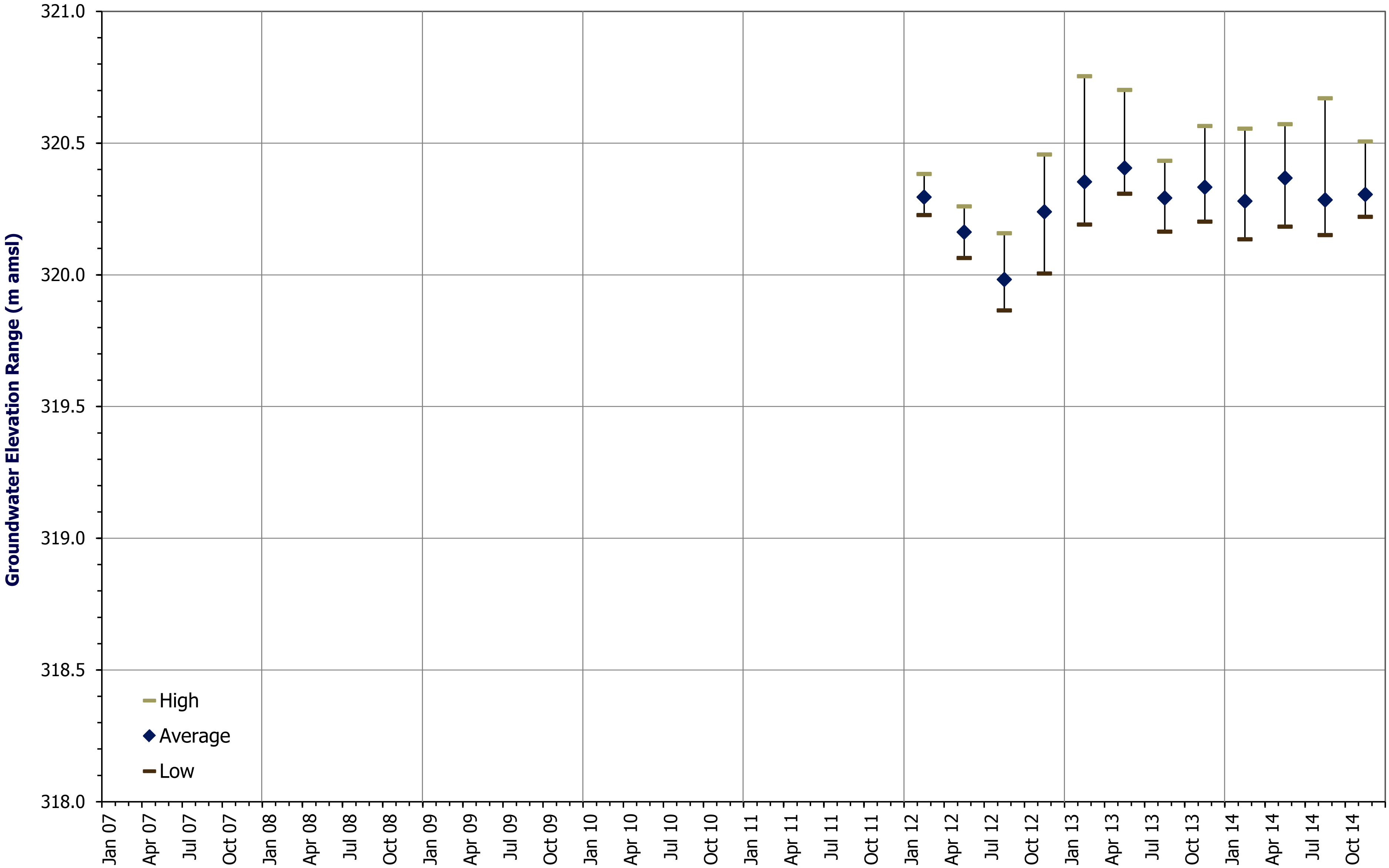
Quarterly Groundwater Elevation Range - MW126



Quarterly Groundwater Elevation Range - MW127



Quarterly Groundwater Elevation Range - MW128



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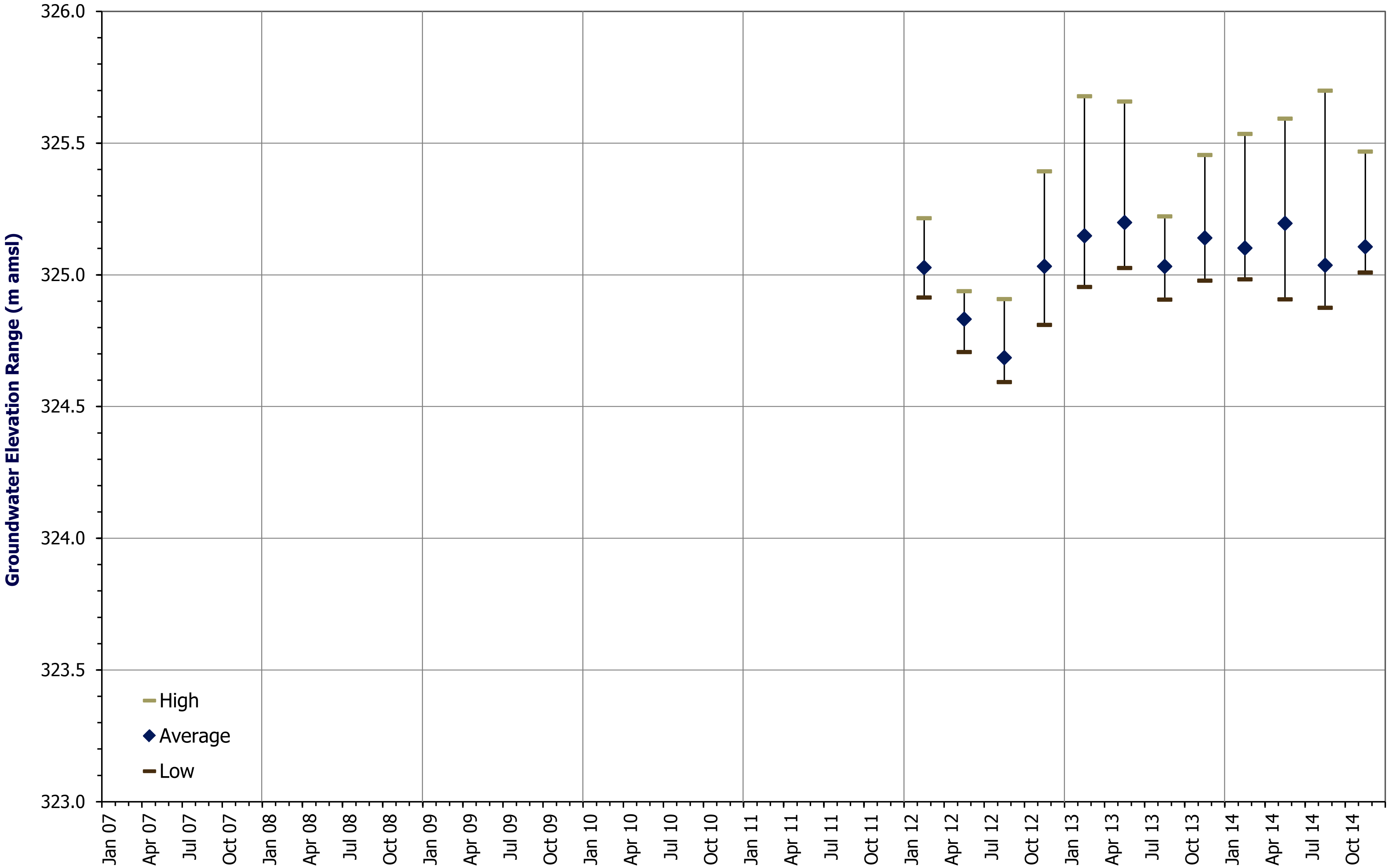
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014

Graph I-20

Quarterly Groundwater Elevation Range - MW129



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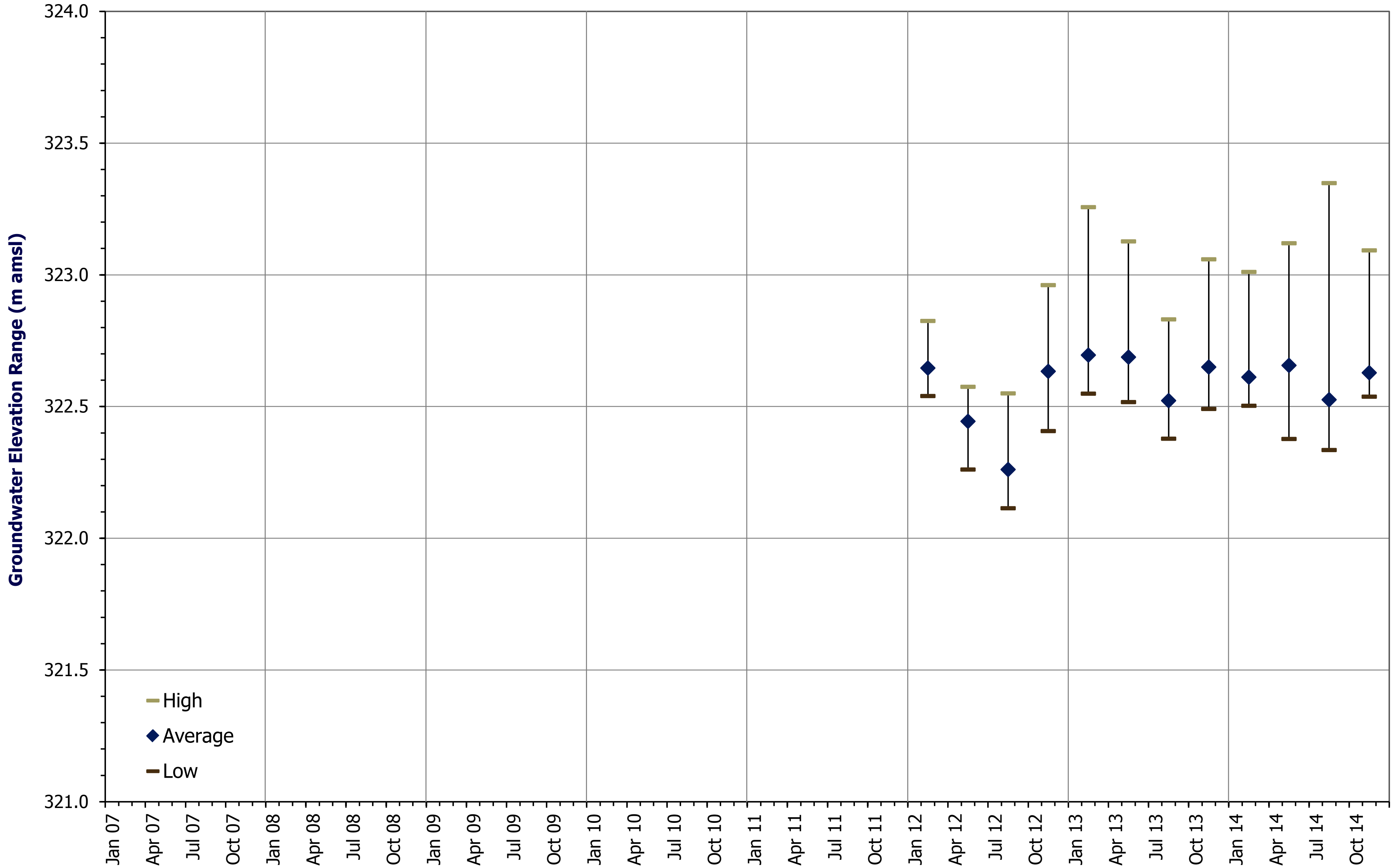
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014

Graph I-21

Quarterly Groundwater Elevation Range - MW130A



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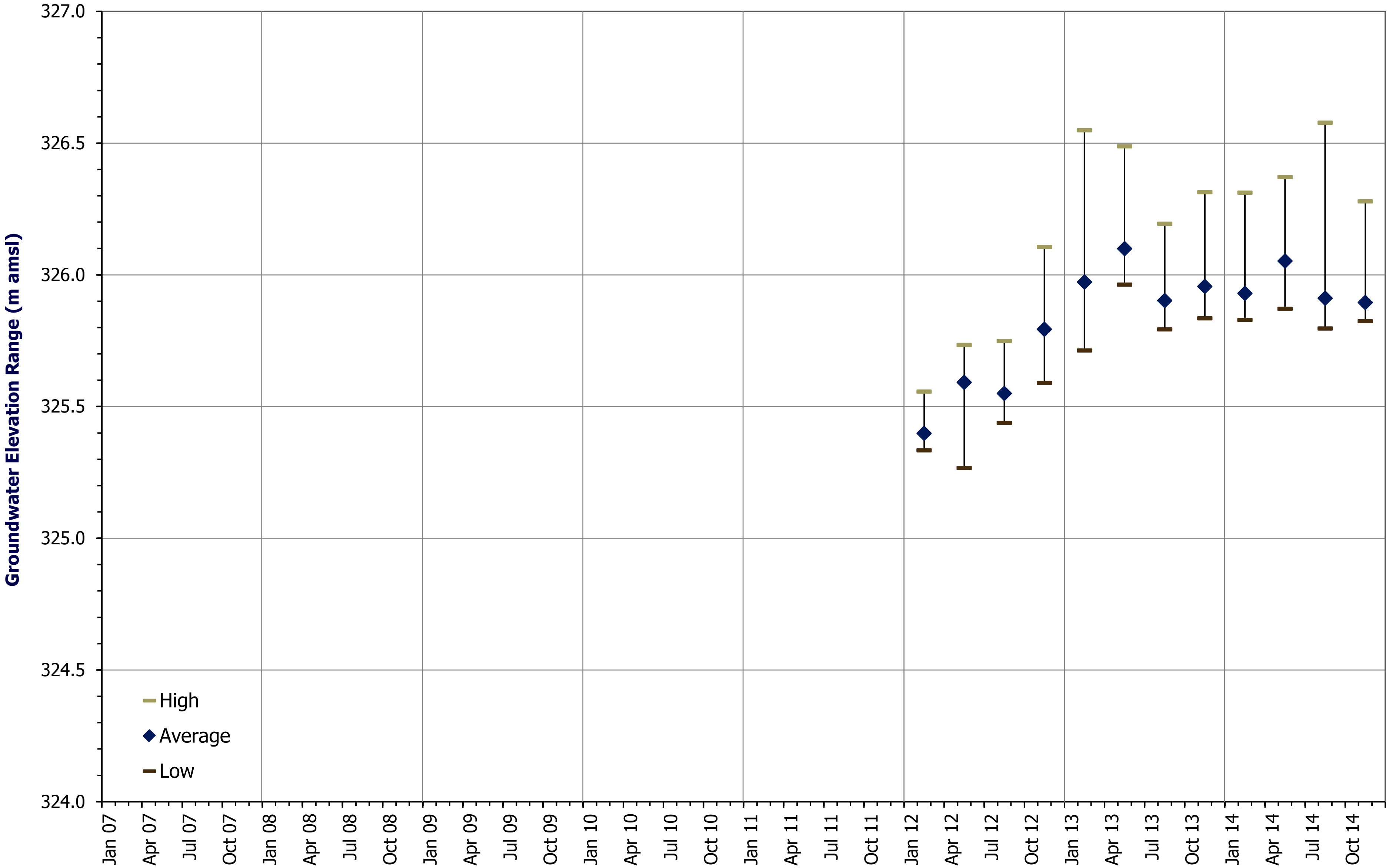
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Graph I-22**

Quarterly Groundwater Elevation Range - MW131



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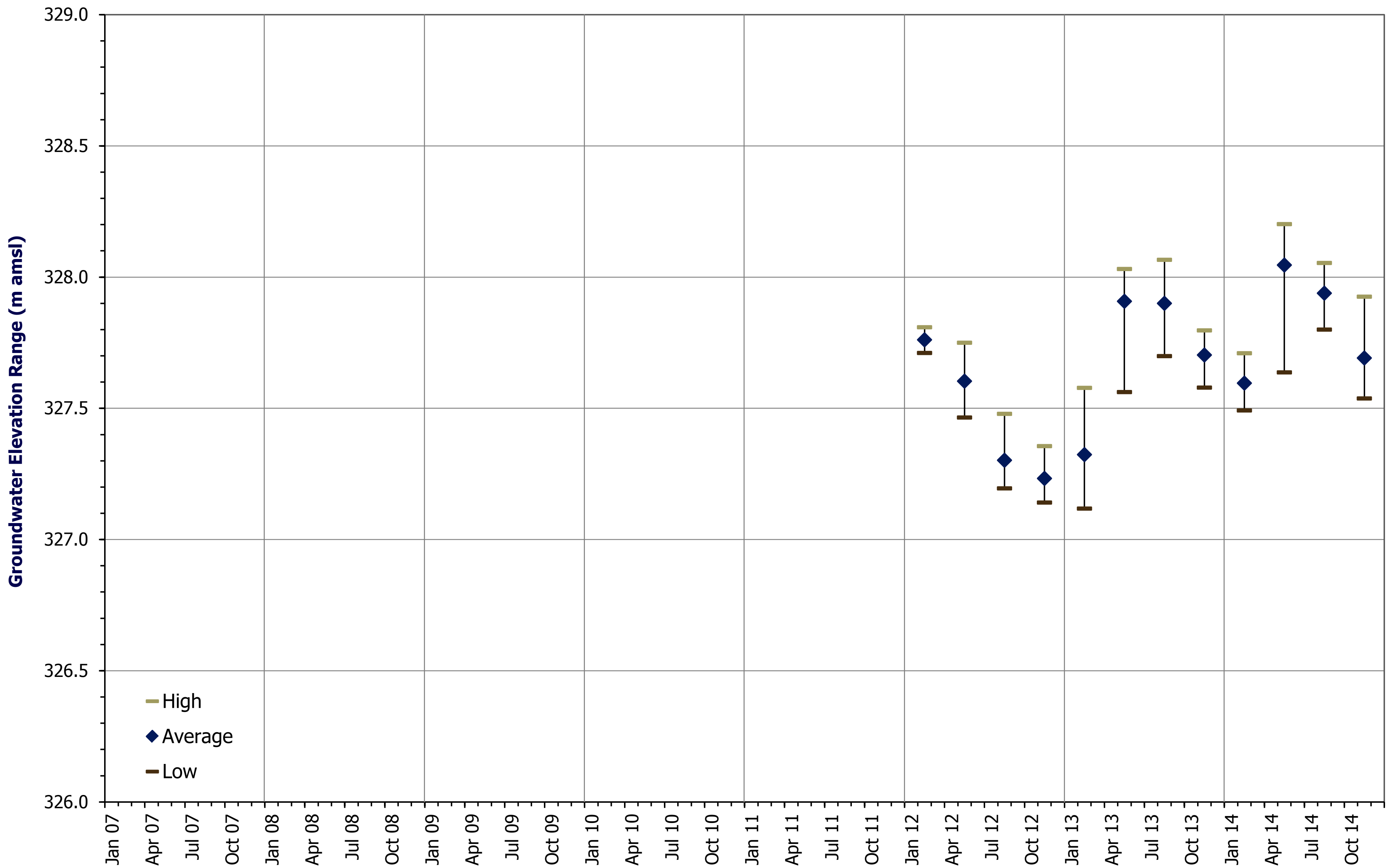
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Graph I-23**

Quarterly Groundwater Elevation Range - MW132



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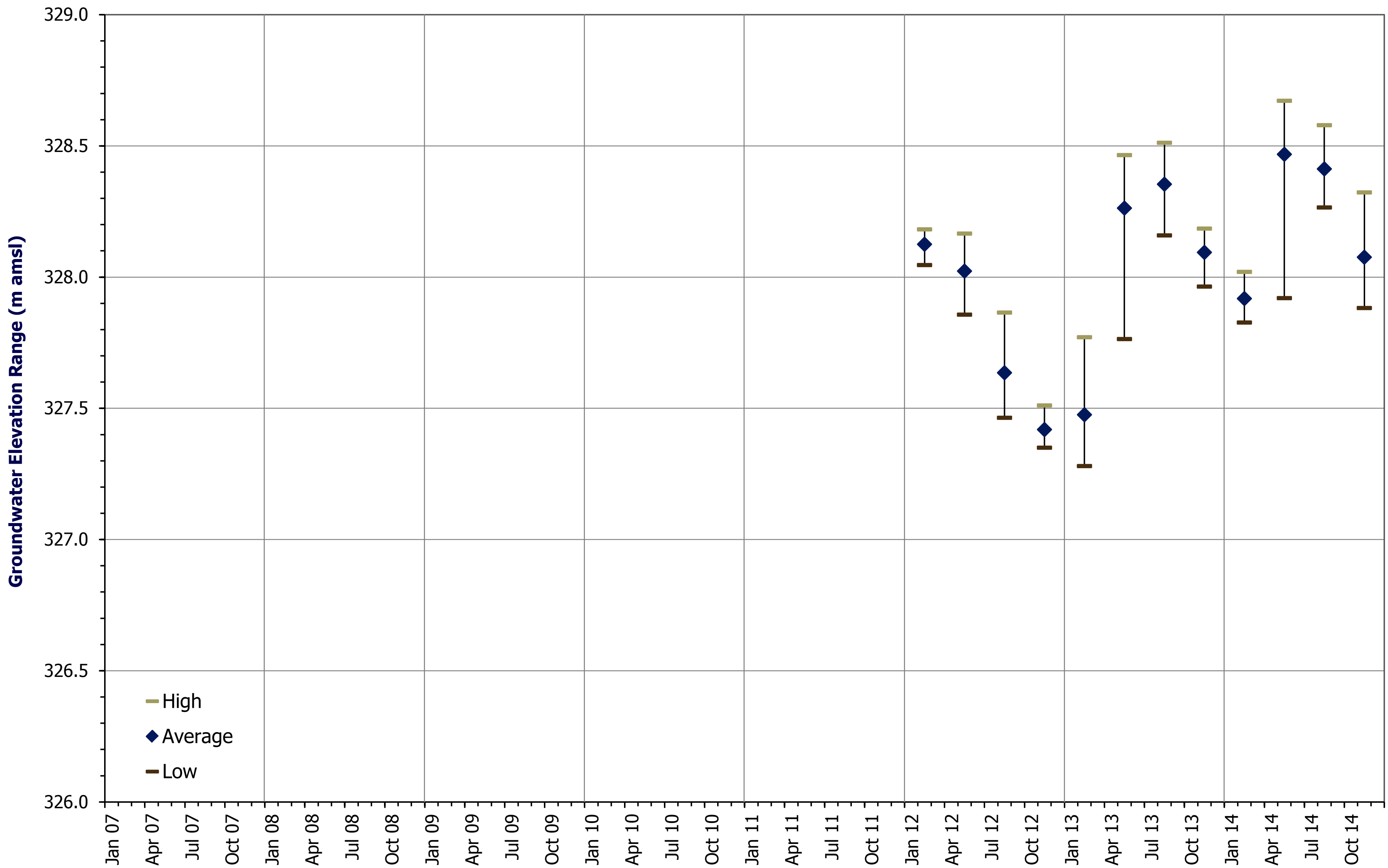
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Graph I-24**

Quarterly Groundwater Elevation Range - MW133

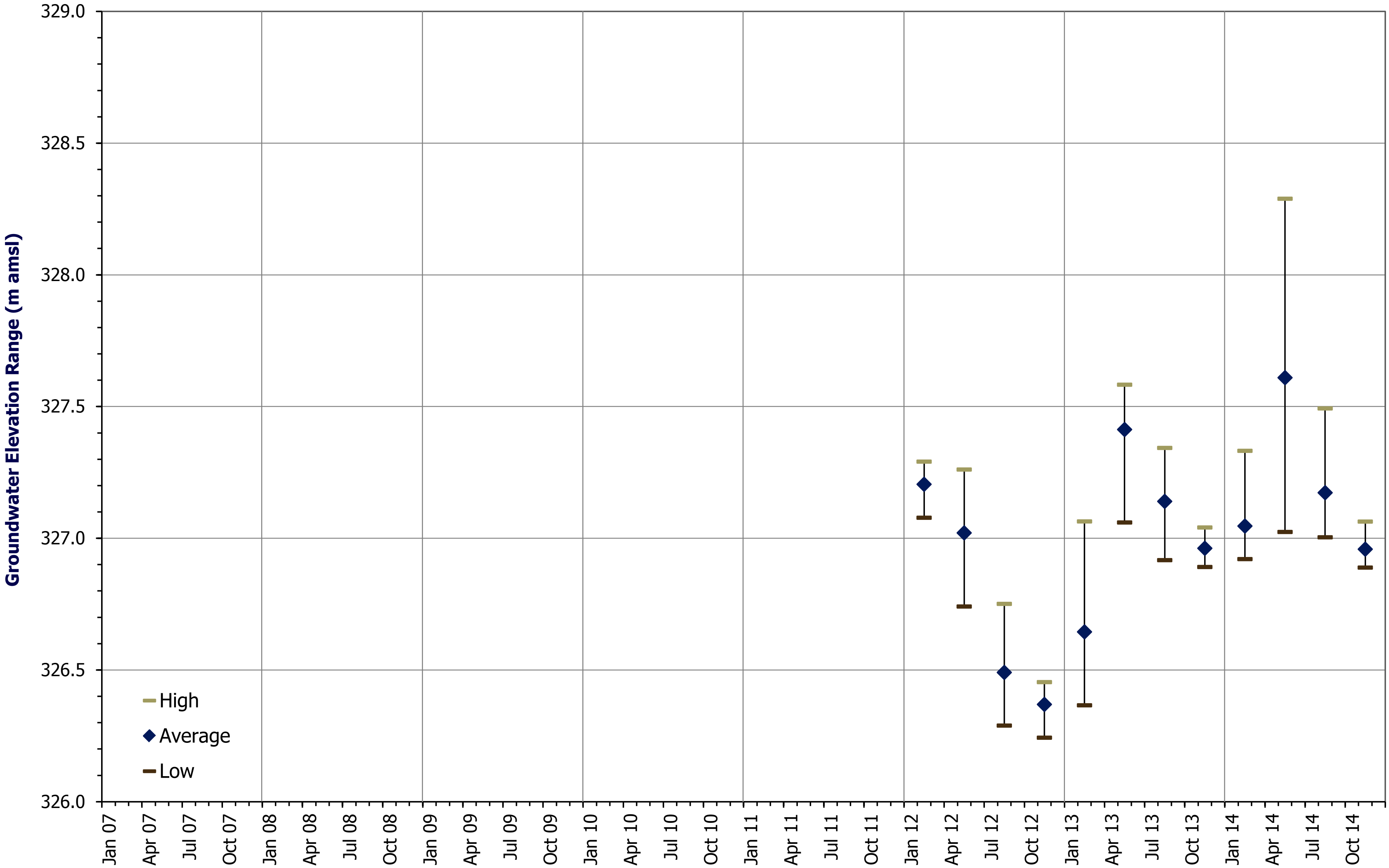


Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Graph I-25**

Quarterly Groundwater Elevation Range - MW134



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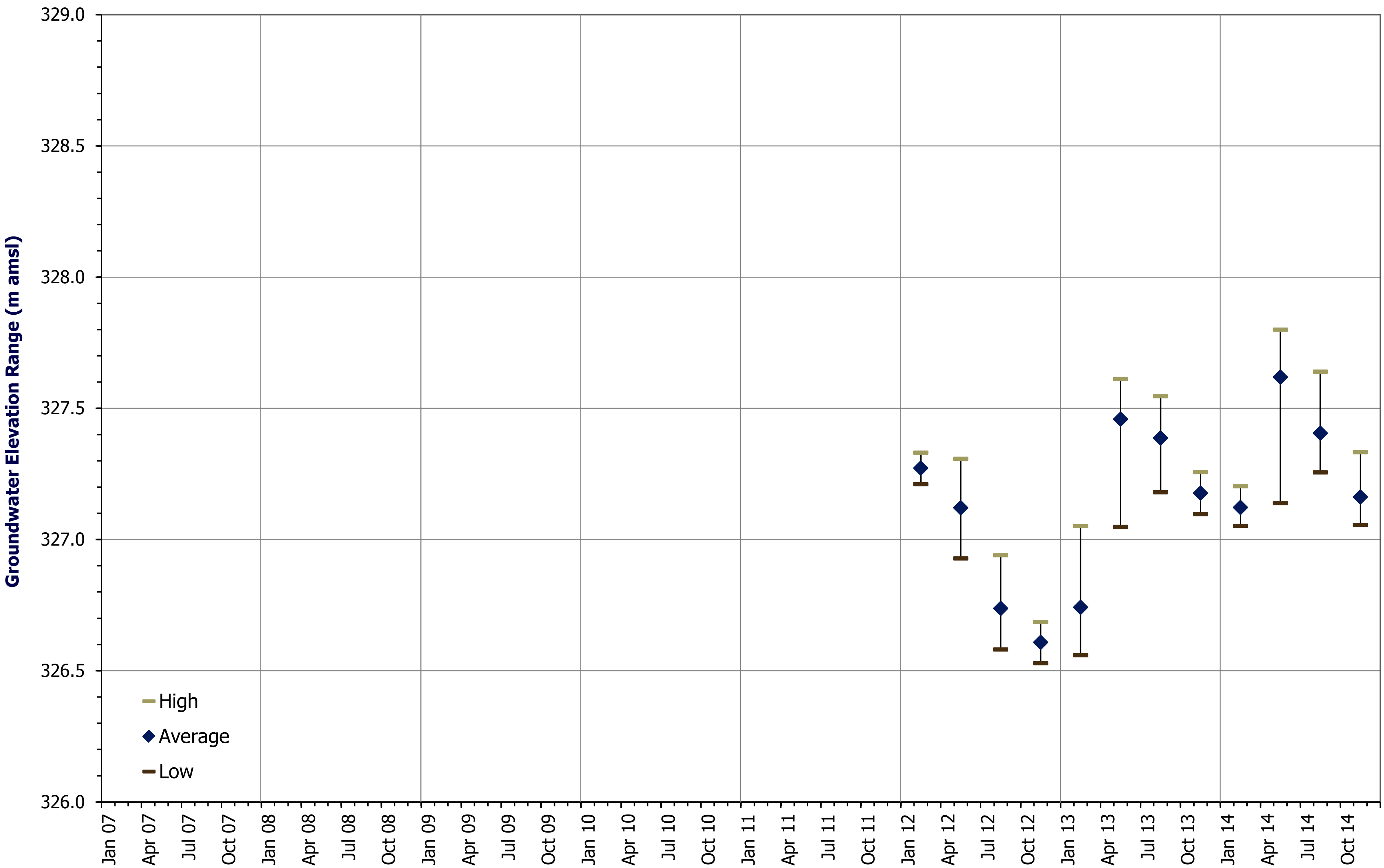
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Graph I-26**

Quarterly Groundwater Elevation Range - MW135



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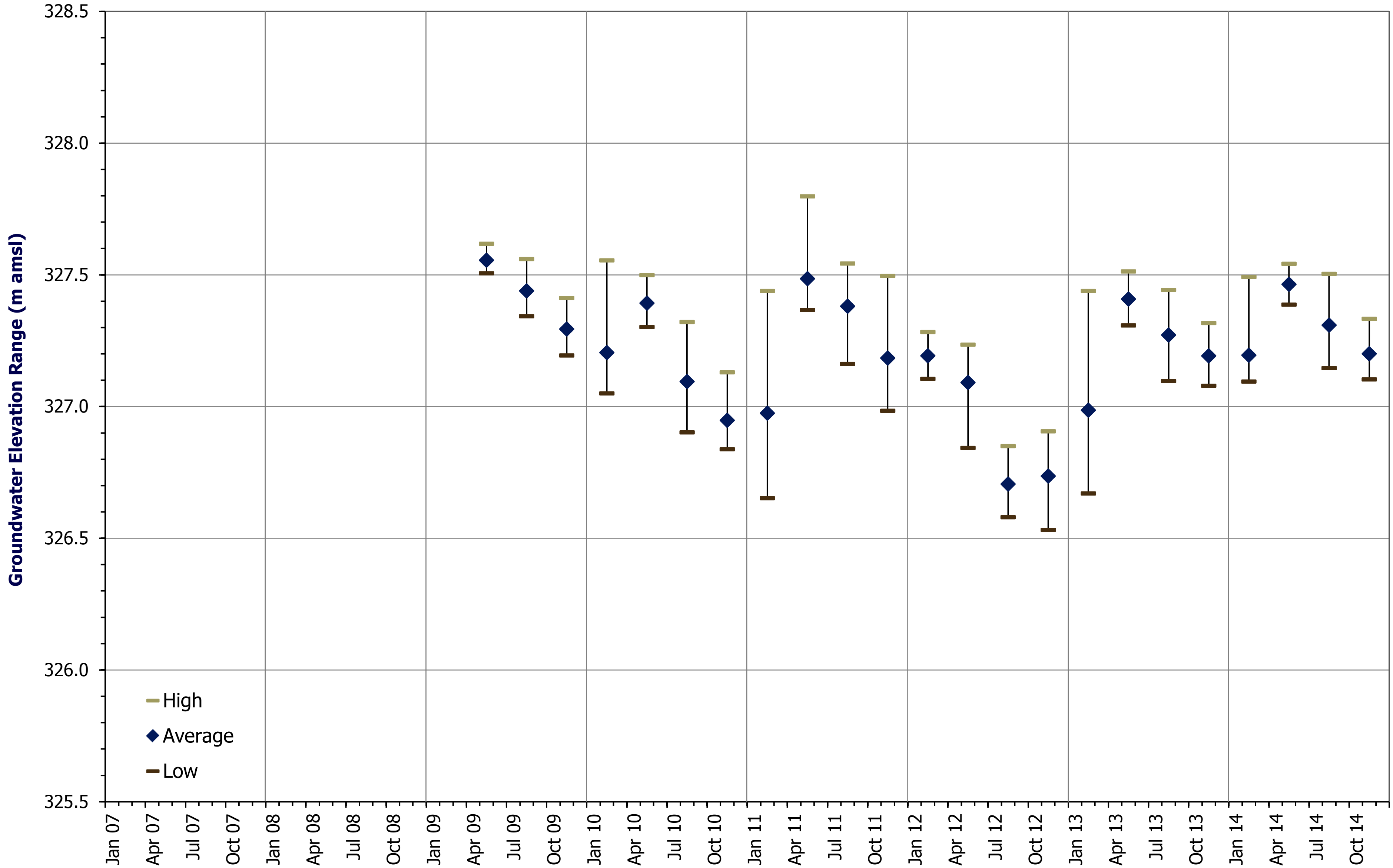
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014

Graph I-27

Quarterly Groundwater Elevation Range - PZ-1D



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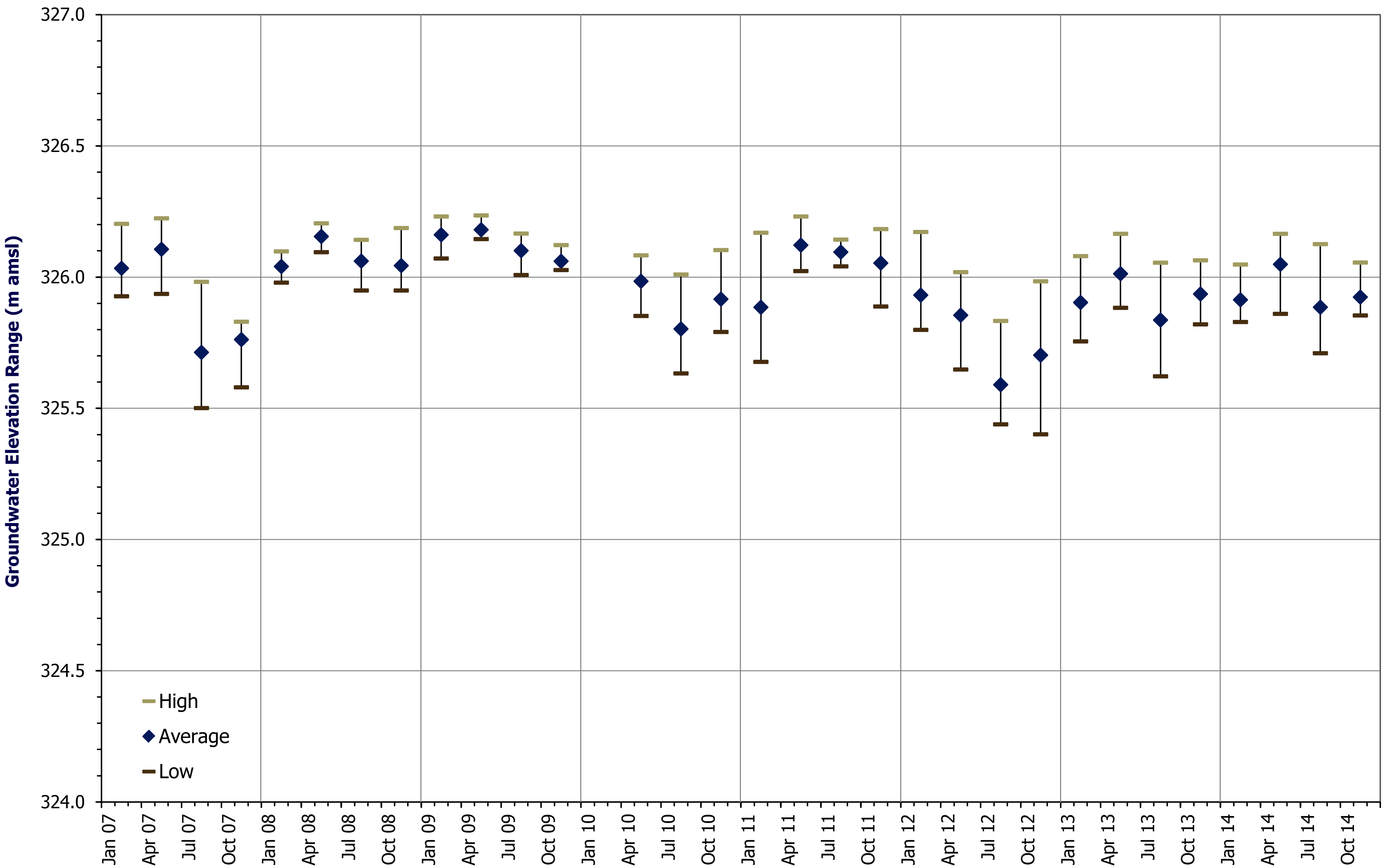
Graph I-28

Quarterly Groundwater Elevation Range - PZ-2D



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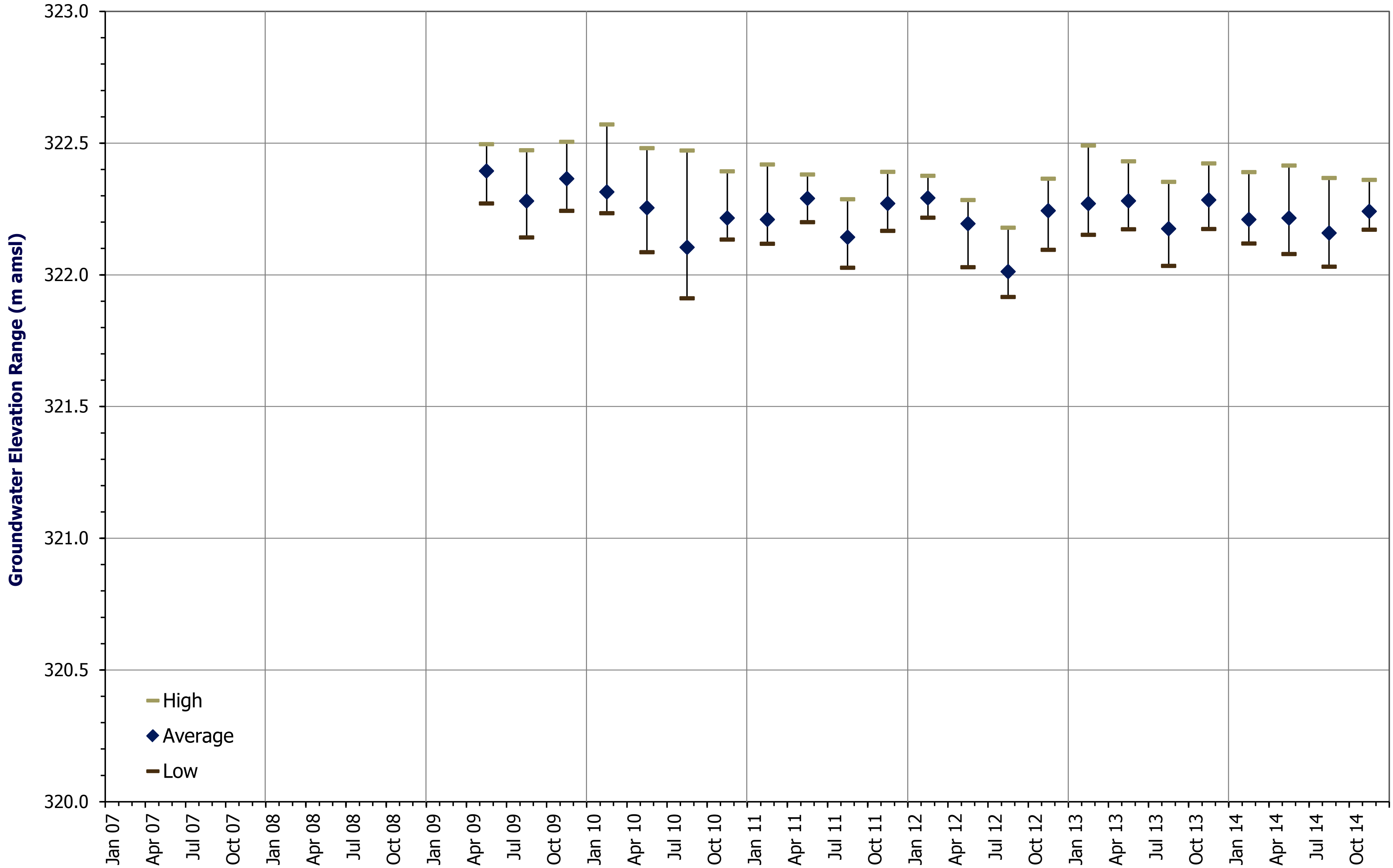
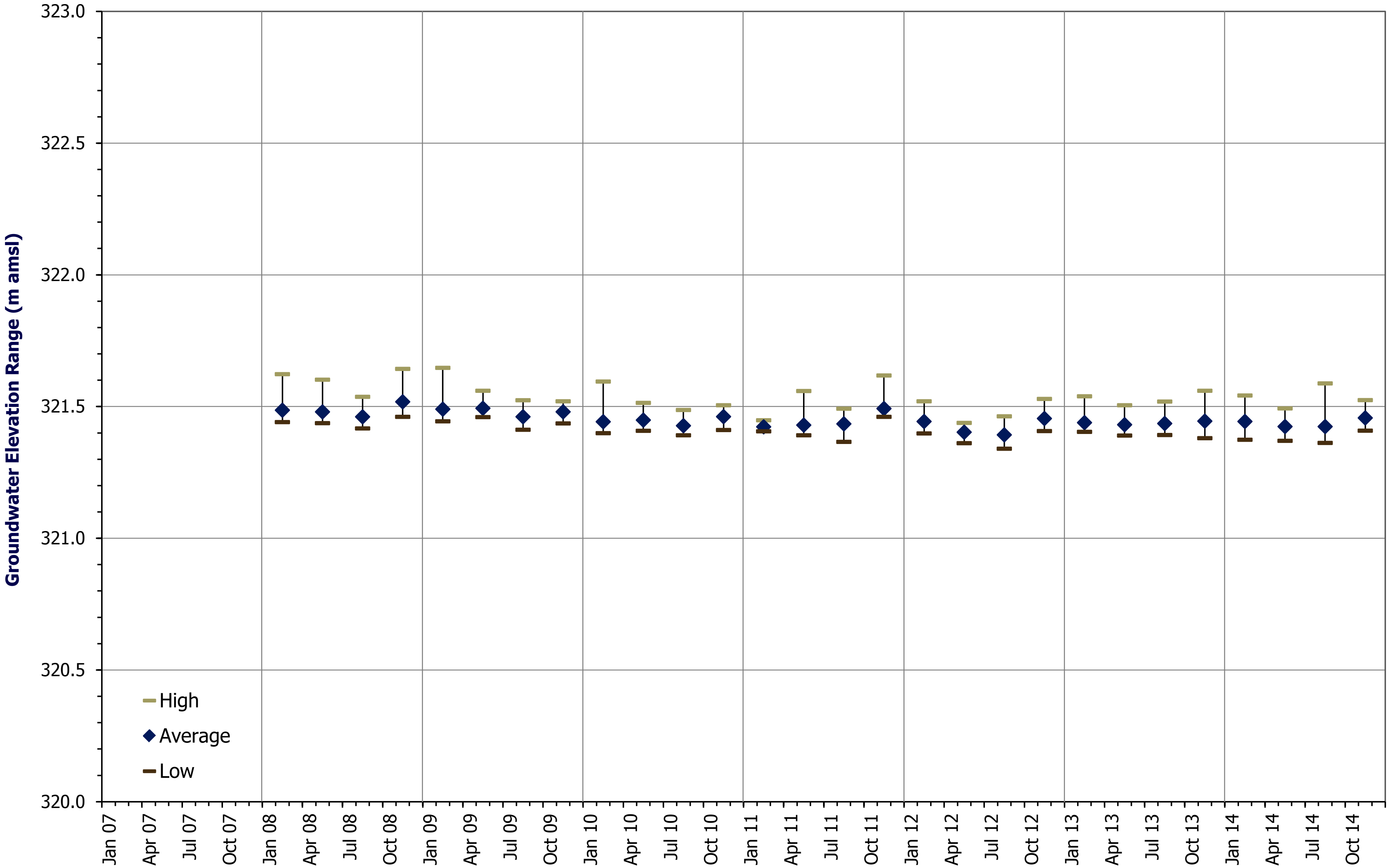
Graph I-29

Quarterly Groundwater Elevation Range - PZ-4D



Quarterly Groundwater Elevation Range - PZ-7D



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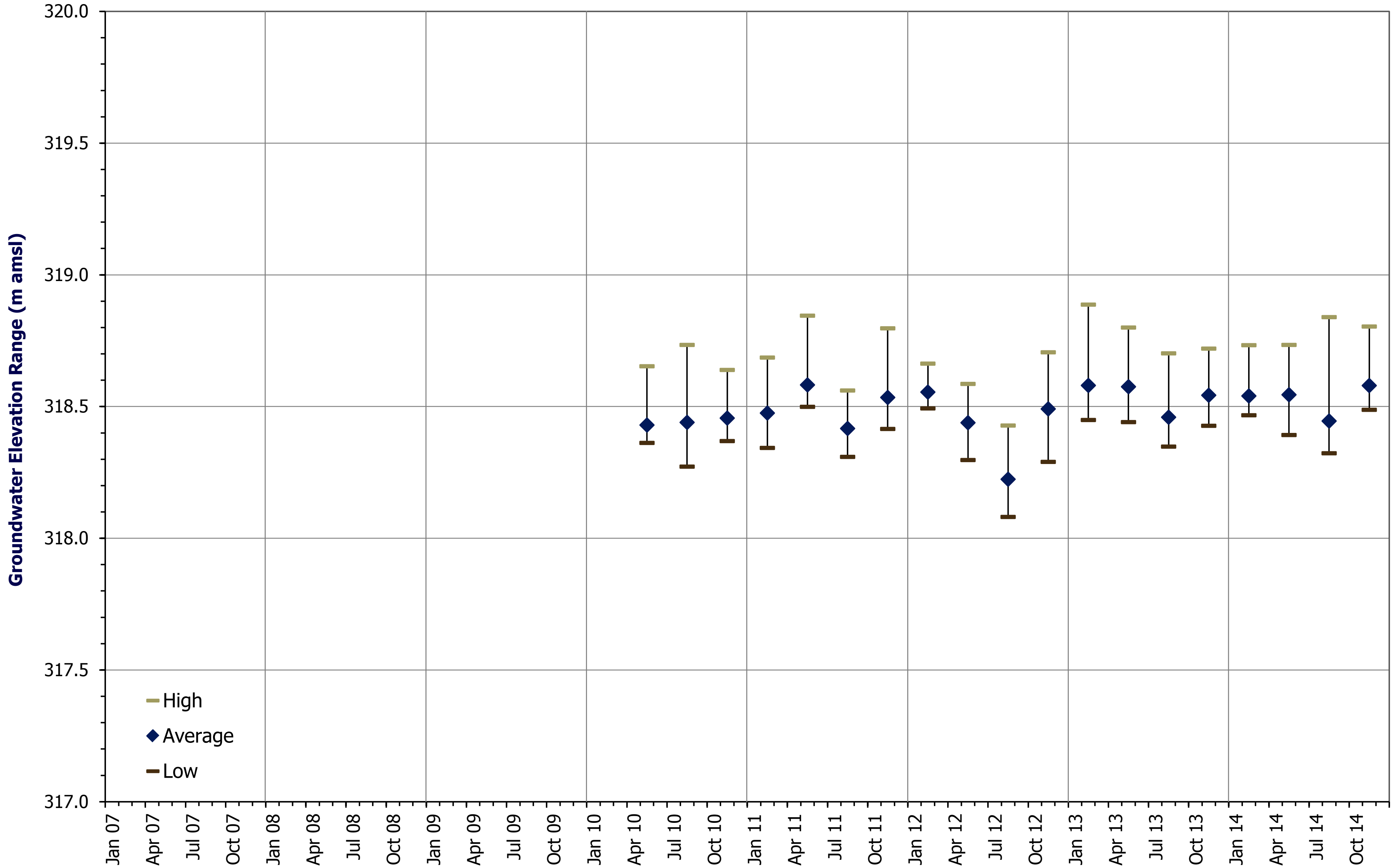
December 2014 **Graph I-31**

Quarterly Groundwater Elevation Range - PZ-8D



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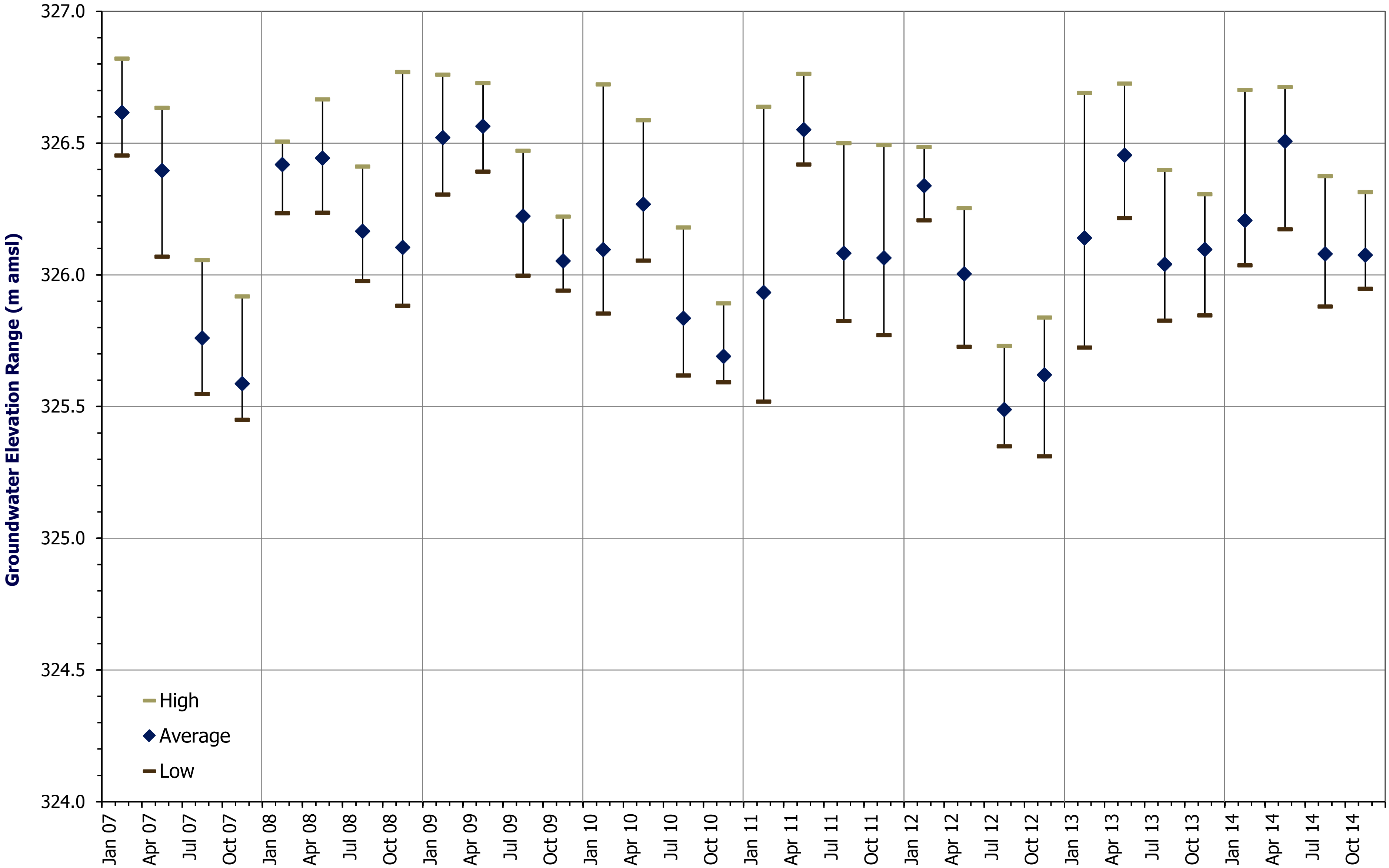
December 2014

Graph I-32

Quarterly Groundwater Elevation Range - PZ-9D



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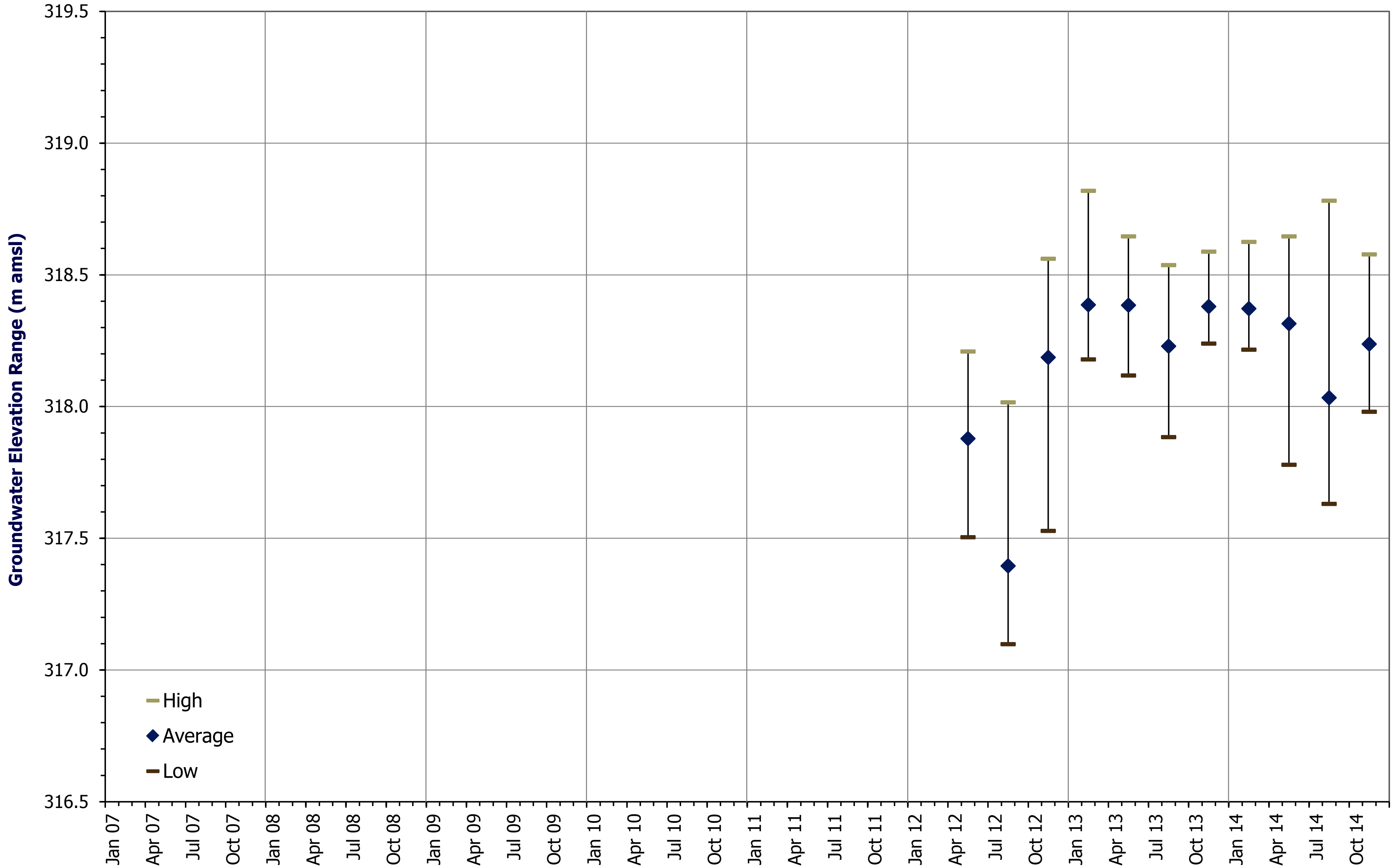
December 2014

Graph I-33

Quarterly Groundwater Elevation Range - PZ-10D

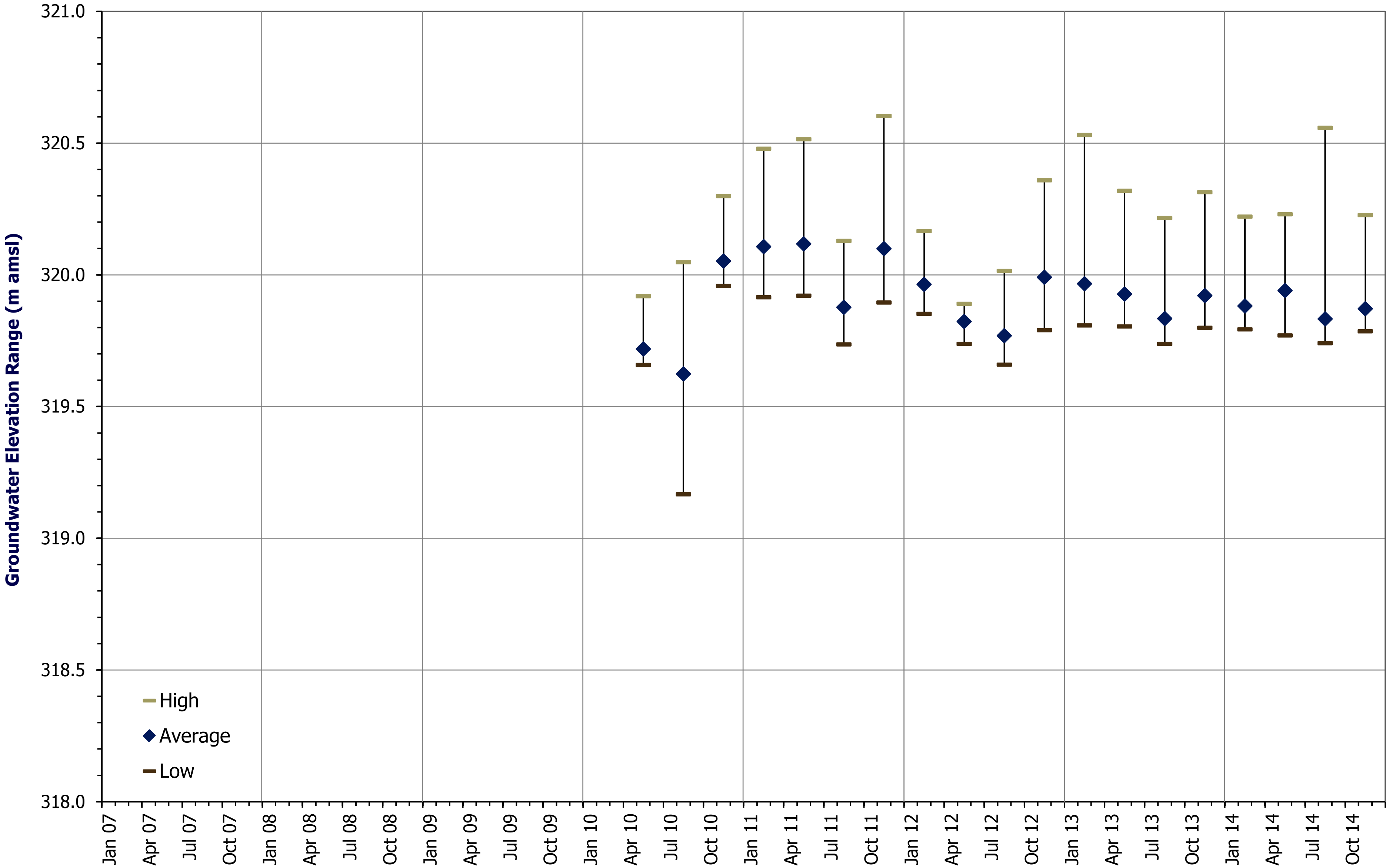


Banks Groundwater Engineering Limited

Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014 **Graph I-34**

Quarterly Groundwater Elevation Range - PZ-11D



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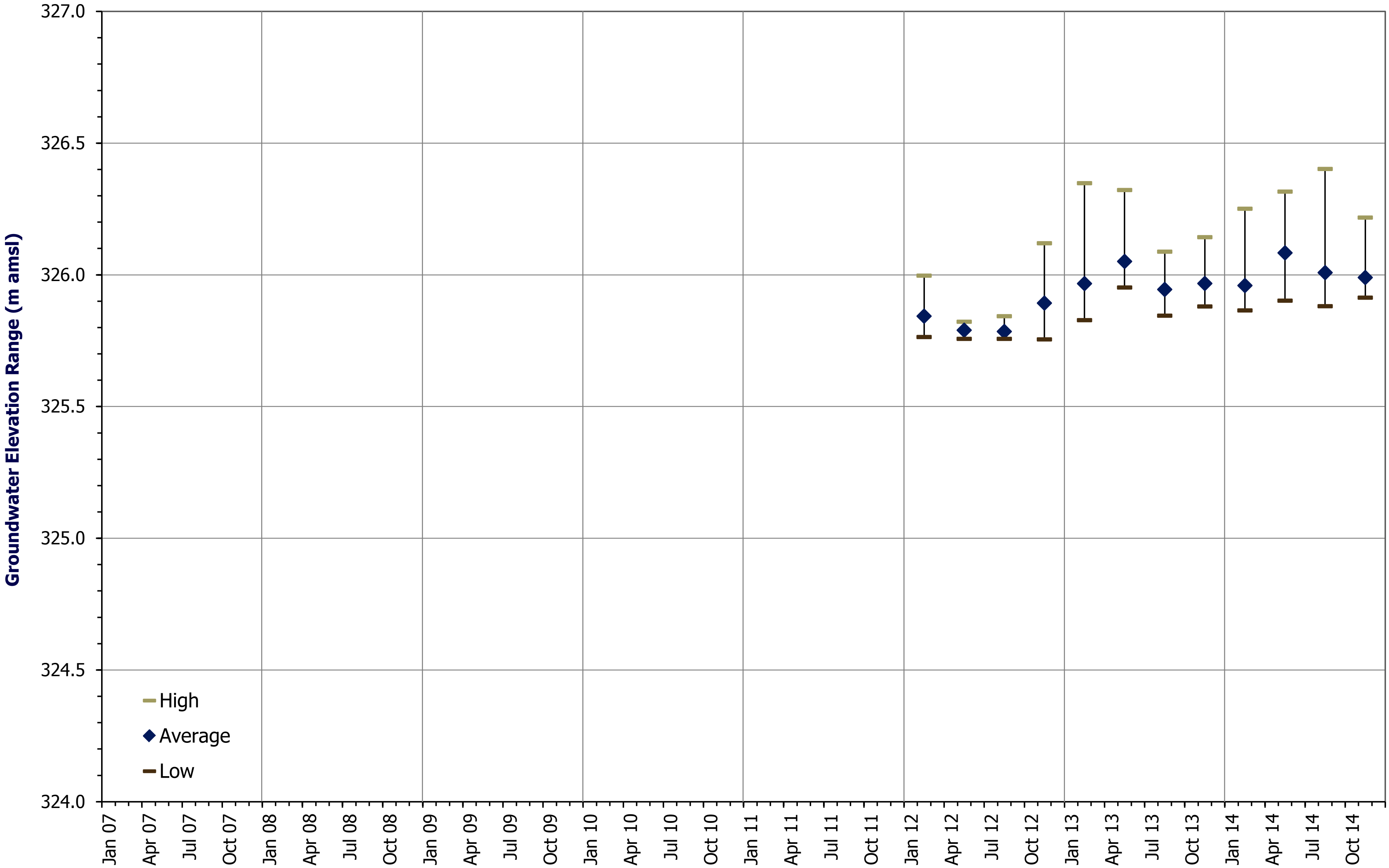
Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014

Graph I-35

Quarterly Groundwater Elevation Range - PZ-12D



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Hanlon Creek Business Park - Groundwater Monitoring Program

December 2014

Graph I-36

Appendix J

Groundwater Quality Monitoring Data 2003 – 2014

Hanlon Creek Business Park - Groundwater Monitoring Program
Groundwater Quality

	Parameter (units)	ODWQS	PWQO	RDL			Monitoring Wells																				
							001					003								004							
				2003	2008-10	2011-14	2003	2008	2009	2010	2011	2003	2008	2009	2010	2011	2012	2013	2014	2003	2008	2009	2010	2011	2012	2013	2014
Anions	Chloride (mg/L)	250		2.0	0.10	0.10 - 0.50	ns	221	245	311	300	ns	37.6	37.4	38.8	39.5	36.9	38.6	40.5	63.0	48.9	55.3	48.5	59.7	64.1	64.5	61.8
	Fluoride (mg/L)	1.5		0.10	0.05	0.05 - 1.25	ns	0.08	<0.05	<0.05	<0.05	ns	<0.05	<0.05	<0.05	<0.05	<0.05	<0.25	<0.50	<0.10	0.08	<0.05	0.07	<0.05	<0.05	<0.25	<1.25
	Nitrate as N (mg/L)	10.0		0.10	0.05	0.05 - 1.25	ns	4.88	3.93	3.09	3.36	ns	11.9	7.79	5.66	4.73	5.80	5.34	6.44	19.0	10.7	12	9.6	7.85	9.43	13.3	13.7
	Nitrite as N (mg/L)	1.0		0.10	0.05	0.05 - 1.25	ns	<0.05	<0.05	<0.05	<0.05	ns	<0.05	<0.05	<0.05	<0.05	<0.05	<0.25	<0.50	<0.10	<0.05	<0.05	<0.05	<0.05	<0.05	<0.25	<1.25
	Phosphate-P (ortho) (mg/L)			0.30	0.10	0.10 - 2.50	ns	<0.10	<0.10	<0.10	<0.10	ns	<0.10	<0.10	<0.10	<0.10	<0.10	<0.50	<1.00	<0.30	<0.10	<0.10	<0.10	<0.10	<0.10	<0.50	<2.50
	Sulphate (mg/L)	500		2.0	0.10	0.10 - 0.50	ns	28.4	24	24.2	23.7	ns	18.0	16.3	14.3	16.9	14.4	14.2	13.5	25.0	20.3	21.4	18.9	18.2	18.8	17.9	20.4
Metals	Aluminum (mg/L)	0.1	0.075	0.01	0.004	0.004	ns	0.063	<0.004	<0.004	0.009	ns	2.56	<0.004	<0.004	0.018	0.006	0.004	<0.004	<0.01	0.648	0.009	<0.004	0.008	0.005	0.008	<0.004
	Antimony (mg/L)	0.006	0.02	0.005	0.006	0.003	ns	<0.006	<0.006	<0.006	<0.003	ns	<0.006	<0.006	<0.006	<0.003	<0.003	<0.003	<0.003	<0.005	<0.006	<0.006	<0.006	<0.003	<0.003	<0.003	<0.003
	Arsenic (mg/L)	0.025	0.005	0.001	0.003	0.003	ns	<0.003	<0.003	<0.003	<0.003	ns	0.010	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.001	0.005	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Barium (mg/L)	1.0		0.01	0.002	0.002	ns	0.627	0.108	0.142	0.12	ns	0.312	0.057	0.052	0.049	0.056	0.046	0.053	0.15	0.371	0.126	0.116	0.087	0.115	0.098	0.113
	Beryllium (mg/L)		1.1	0.001	0.001	0.001	ns	<0.001	<0.001	<0.001	<0.001	ns	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Bismuth (mg/L)			0.001	0.002	0.002	ns	<0.002	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Boron (mg/L)	5.0	0.2	0.05	0.010	0.010	ns	0.015	0.012	0.015	0.01	ns	0.016	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.05	0.016	0.013	0.011	0.01	0.012	<0.010	0.012
	Cadmium (mg/L)	0.005	0.0005	0.0001	0.002	0.001	ns	0.006	<0.002	<0.002	<0.002	ns	0.010	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.0001	0.011	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002
	Calcium (mg/L)	200		0.5	0.05	0.05	ns	86.2	95.7	115	97.8	ns	87.2	86.6	87	80.5	74.8	83.6	75.4	130	92.5	119	103	93.7	98.5	110	111
	Chromium (mg/L)	0.05	0.0089	0.001	0.003	0.003	ns	0.016	0.004	<0.003	<0.003	ns	0.006	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.004	0.004	0.004	<0.003	<0.003	0.004	<0.003	<0.003
	Cobalt (mg/L)		0.0009	0.0008	0.001	0.001	ns	0.008	<0.001	<0.001	<0.001	ns	0.027	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0008	0.017	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Copper (mg/L)	1.0	0.005	0.001	0.003	0.002	ns	0.004	<0.003	<0.003	<0.003	ns	0.082	<0.003	<0.003	<0.003	0.002	<0.003	<0.003	0.002	0.009	0.003	<0.003	<0.003	0.002	<0.003	<0.003
	Iron (mg/L)	0.3	0.3	0.05	0.010	0.010	ns	0.63	<0.010	<0.010	<0.010	ns	3.20	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.13	0.592	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
	Lead (mg/L)	0.010	0.025	0.001	0.002	0.002	ns	<0.001	<0.002	<0.002	<0.002	ns	0.325	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Magnesium (mg/L)			0.5	0.05	0.05	ns	27.3	28.9	34.7	29.4	ns	24.3	27.3	24.8	22.4	21.1	23.5	22.1	36	25	32.2	29.1	26.9	27.2	30.5	31.2
	Manganese (mg/L)	0.05		0.001	0.002	0.002	ns	4.87	<0.002	<0.002	<0.002	ns	3.53	<0.002	<0.002	0.002	<0.002	<0.002	<0.002	0.012	3.38	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Molybdenum (mg/L)		0.04	0.001	0.002	0.001	ns	<0.002	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002
	Nickel (mg/L)		0.025	0.002	0.003	0.003	ns	0.028	<0.003	0.005	<0.003	ns	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.002	<0.003	<0.003	0.004	<0.003	<0.003	<0.003	<0.003
	Phosphorus (mg/L)		0.01	0.05	0.05	0.05	ns	0.13	<0.05	<0.05	<0.05	ns	0.97	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.16	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Potassium (mg/L)			0.5	0.05	0.05	ns	3.07	1.73	2.06	1.85	ns	2.24	1.79	1.67	1.57	1.51	1.77	1.58	15	10.3	13.4	12	6.33	10.4	8.32	17.4
	Selenium (mg/L)	0.01	0.1	0.005	0.004	0.004	ns	<0.004	<0.004	<0.004	<0.004	ns	0.006	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
	Silver (mg/L)		0.0001	0.0001	0.002	0.002	ns	<0.0001	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.0001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Sodium (mg/L)	20		0.5	0.05	0.05	ns	127	105	162	167	ns	14	17.4	15.4	13.7	14.8	14.9	15.5	24	18.6	22.3	20.7	19.5	25	25.6	27.8
	Strontium (mg/L)			0.001	0.005	0.005	ns	1.91	0.113	0.155	0.128	ns	0.994	0.094	0.096	0.106	0.109	0.091	0.095	0.16	1.98	0.138	0.132	0.131	0.129	0.128	0.123
	Thallium (mg/L)		0.0003	0.0003	0.006	0.006	ns	<0.0003	<0.006	<0.006	<0.006	ns	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	0.0004	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
	Tin (mg/L)			0.001	0.002	0.002	ns	<0.002	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Titanium (mg/L)			0.002	0.002	0.002	ns	0.005	<0.002	<0.002	<0.002	ns	0.016	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.009	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Uranium (mg/L)	0.02	0.005	0.005	0.002	0.002	ns	0.002	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.005	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Vanadium (mg/L)		0.006	0.001	0.002	0.002	ns	0.002	<0.002	0.003	<0.002	ns	0.007	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.009	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Zinc (mg/L)	5	0.03	0.003	0.005	0.005	ns	0.309	0.023	0.016	0.012	ns	1.19	0.011	0.015	0.033	0.02	0.014	0.011	0.018	0.835	0.042	0.032	0.027	0.031	0.032	0.026
Wet Chemistry	Alkalinity (CaCO3) (mg/L)	500		10	5	5	ns	299	275	297	298	ns	252	262	272	248	259	254	243	320	293	326	305	303	330	297	338
	Bicarbonate (CaCO3) (mg/L)			10	5	5	ns	299	275	297	298	ns	252	262	272	248	259	254	243	319	293	326	305	303	330	297	338
	Carbonate (CaCO3) (mg/L)			10	5	5	ns	<5	<5	<5	<5	ns	<5	<5	<5	<5	<5	<5	<5	<10	<5	<5	<5	<5	<5	<5	<5
	Colour (TCU)	5		1	5	5	ns	<5	<5	5	<5	ns	<5	<5	7	<5	<5	<5	<5	27	<5	<5	7	<5	<5	<5	<5
	Total Organic Carbon (mg/L)				0.5	0.5	ns	36.6	1.4	1.8	1.5	ns	2.6	4.2	1.6	1	6.4	2	2.4	na	1.0	2	1.8	1.2	4.9	2.4	2
	DOC (mg/L)	5		0.7	0.5	0.5	ns	1.4	1.5	1.8	1.5	ns	2.6	1.9	1.6	0.9	2	1	2.2	1.3	1.0	2	1.6	1	1.8	1.5	2.1
	Hardness (CaCO3) (mg/L)	100		10	10	10	ns	328	358	430	365	ns	318	329	319	293	274	306	279	473	334	430	377	345	358	400	406
	Ammonia as N (mg/L)			0.05	0.02	0.02	ns	<0.02	<0.02	0.15	<0.02	ns	<0.02	<0.02	<0.02	0.59	<0.02	<0.02	0.03	<0.05	0.17	<0.02	<0.02	<0.02	0.03	<0.02	0.04
	Conductivity (us/cm)			3	2	2	ns	1160	1290	1450	1360	ns	658	667	617	623	616	666	622	950	739	897	762	785	859	936	965
	pH	8.5	6.5 - 8.5	0.1	N/A	N/A	ns	7.84	8.18	8.11	7.76	ns	8.14	7.90	8.05	7.98	7.94	8.23	8.07	7.3	8.11	7.83	8.05	7.72	7.99	7.87	8.04
Calculated Values	Anion sum (meq/L)			0.01			ns	12.2	13.2	14.5	15.2	ns	7.33	7.19	6.34	6.76	6.93	6.85	6.74	10.1	8.43		7.55	8.68	9.47	9.08	9.91
	Cation sum (meq/L)			0.01			ns	12.1	11.8	15.7	14.6	ns	7.02	7.37	7.1	6.54	6.15	6.8	6.3	10.9	7.76		8.74	7.9	8.51	9.33	9.76
	% Difference (%)			0.01	0.1	0.1	ns	0.1	5.7	0.8	1.8	ns	2.1	1.2	1	1.7	6	0.3	3.4	7.93	4.1	2.7	1.1	4.7	5.4	1.3	0.7
	Langelier Index			0.0001			ns	0.94	1.28	1.32	0.91	ns	1.18	0.98	1.13	0.98	0.93	1.26	1.04	-0.17	1.24	1.28	1.25	0.85	1.17	1.09	1.29
	Saturation pH (pH units)			0.01			ns	6.9	6.9	6.79	6.85	ns	6.96	6.92	6.92	7	7.01	6.97	7.03	7.47	6.87	6.55	6.8	6.87	6.82	6.78	6.75
	Silica (mg/L)				0.05	0.05	ns	10.6	3.79	9.4	8.49	ns	8.30	3.60	8.11	6.62	6.89	7.5	6.59	20.2	9.64	4.37	9.09	9.27	9.27	10.2	9.32

At or Exceeds ODWQS

* ODWQS: Ontario Drinking Water Quality Standards, PWQO: Provincial Water Quality Objective, RDL: Reported Detection Limit, ns: not sampled, na: not analyzed, anom: anomolous result caused by drilling fluid in well

Hanlon Creek Business Park - Groundwater Monitoring Program

Groundwater Quality

	Parameter (units)	ODWQS	PWQO	RDL			**Monitoring Wells** 005-I				006				101				102			
				2003	2008-10	2011-14	2003	2008	2009	2010	2003	2008	2009	2010	2003	2008	2009	2010	2003	2008	2009	2010
Anions	Chloride (mg/L)	250		2.0	0.10	0.10 - 0.50	190	163	182	233	ns	22.9	36.8	45.3	ns	82.5	101	85.0	ns	46.3	39.9	41.9
	Fluoride (mg/L)	1.5		0.10	0.05	0.05 - 1.25	0.10	<0.05	<0.05	<0.05	ns	0.06	<0.05	<0.05	ns	0.10	0.08	0.07	ns	0.09	<0.05	0.05
	Nitrate as N (mg/L)	10.0		0.10	0.05	0.05 - 1.25	6.80	6.95	4.71	3.72	ns	2.36	5.83	3.38	ns	2.57	2.03	1.72	ns	<0.05	0.05	<0.05
	Nitrite as N (mg/L)	1.0		0.10	0.05	0.05 - 1.25	<0.30	<0.05	<0.05	<0.05	ns	<0.05	<0.05	<0.05	ns	<0.05	<0.05	<0.05	ns	<0.05	<0.05	<0.05
	Phosphate-P (ortho) (mg/L)			0.30	0.10	0.10 - 2.50	<0.30	<0.10	<0.10	<0.10	ns	<0.10	<0.10	<0.10	ns	<0.10	<0.10	<0.10	ns	<0.10	<0.10	<0.10
	Sulphate (mg/L)	500		2.0	0.10	0.10 - 0.50	20.0	18.4	17.2	18.2	ns	9.85	13.8	11.6	ns	23.2	22.3	21.1	ns	38.7	25.6	32.4
Metals	Aluminum (mg/L)	0.1	0.075	0.01	0.004	0.004	<0.01	1.09	<0.004	<0.004	ns	0.067	<0.004	<0.004	ns	0.048	<0.004	<0.004	ns	0.037	0.022	<0.004
	Antimony (mg/L)	0.006	0.02	0.005	0.006	0.003	<0.005	<0.006	<0.006	<0.006	ns	<0.006	<0.006	<0.006	ns	<0.006	<0.006	<0.006	ns	<0.006	<0.006	<0.006
	Arsenic (mg/L)	0.025	0.005	0.001	0.003	0.003	<0.001	<0.003	<0.003	<0.003	ns	0.005	<0.003	<0.003	ns	<0.003	<0.003	<0.003	ns	0.003	<0.003	<0.003
	Barium (mg/L)	1.0		0.01	0.002	0.002	0.10	0.366	0.095	0.11	ns	0.480	0.043	0.047	ns	0.558	0.043	0.042	ns	0.332	0.056	0.062
	Beryllium (mg/L)		1.1	0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	ns	<0.001	<0.001	<0.001	ns	<0.001	<0.001	<0.001	ns	<0.001	<0.001	<0.001
	Bismuth (mg/L)			0.001	0.002	0.002	<0.001	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002
	Boron (mg/L)	5.0	0.2	0.05	0.010	0.010	<0.05	0.015	<0.010	<0.010	ns	0.016	<0.010	<0.010	ns	0.012	0.011	0.012	ns	0.012	0.011	<0.010
	Cadmium (mg/L)	0.005	0.0005	0.0001	0.002	0.001	<0.0001	0.020	<0.002	<0.002	ns	0.008	<0.002	<0.002	ns	0.001	<0.002	<0.002	ns	0.0012	<0.002	<0.002
	Calcium (mg/L)	200		0.5	0.05	0.05	110	83.6	103	99.6	ns	67.5	78.3	78.4	ns	76.2	83.5	84.4	ns	83.7	85.1	82.4
	Chromium (mg/L)	0.05	0.0089	0.001	0.003	0.003	0.004	0.012	0.006	<0.003	ns	<0.003	<0.003	<0.003	ns	0.013	<0.003	<0.003	ns	0.013	<0.003	<0.003
	Cobalt (mg/L)		0.0009	0.0008	0.001	0.001	<0.0008	0.028	<0.001	<0.001	ns	0.008	<0.001	<0.001	ns	0.006	<0.001	<0.001	ns	0.015	<0.001	<0.001
	Copper (mg/L)	1.0	0.005	0.001	0.003	0.002	0.005	0.058	<0.003	<0.003	ns	<0.003	<0.003	<0.003	ns	<0.003	<0.003	<0.003	ns	0.005	<0.003	<0.003
	Iron (mg/L)	0.3	0.3	0.05	0.010	0.010	0.12	<0.010	<0.010	<0.010	ns	<0.010	<0.010	<0.010	ns	0.40	<0.010	<0.010	ns	4.65	0.684	<0.010
	Lead (mg/L)	0.010	0.025	0.001	0.002	0.002	<0.001	0.082	<0.002	<0.002	ns	<0.002	<0.002	<0.002	ns	<0.001	<0.002	<0.002	ns	<0.001	<0.002	<0.002
	Magnesium (mg/L)			0.5	0.05	0.05	44	27	31.9	30.9	ns	22.4	24.5	23.7	ns	24.4	27	27.2	ns	24.9	26.9	25.9
	Manganese (mg/L)	0.05		0.001	0.002	0.002	0.046	3.74	<0.002	<0.002	ns	2.50	<0.002	<0.002	ns	4.13	<0.002	<0.002	ns	4.26	0.152	0.076
	Molybdenum (mg/L)		0.04	0.001	0.002	0.001	0.004	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	ns	0.003	<0.002	<0.002
	Nickel (mg/L)		0.025	0.002	0.003	0.003	0.004	0.022	<0.003	0.009	ns	<0.003	<0.003	<0.003	ns	0.009	<0.003	0.004	ns	0.022	<0.003	0.003
	Phosphorus (mg/L)		0.01	0.05	0.05	0.05	<0.05	0.18	<0.05	<0.05	ns	<0.05	<0.05	<0.05	ns	0.03	<0.05	<0.05	ns	1.07	0.02	<0.05
	Potassium (mg/L)			0.5	0.05	0.05	3.4	2.26	1.48	1.57	ns	1.11	0.81	0.79	ns	2.46	1.41	1.32	ns	2.12	1.01	1.64
	Selenium (mg/L)	0.01	0.1	0.005	0.004	0.004	<0.005	<0.004	<0.004	<0.004	ns	<0.004	<0.004	<0.004	ns	<0.004	<0.004	<0.004	ns	<0.004	<0.004	<0.004
	Silver (mg/L)		0.0001	0.0001	0.002	0.002	<0.0001	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	ns	<0.0001	<0.002	<0.002	ns	<0.0001	<0.002	<0.002
	Sodium (mg/L)	20		0.5	0.05	0.05	73	84.6	87.5	123	ns	16	24.9	32.5	ns	53.9	53.5	55.4	ns	39.5	35	37.9
	Strontium (mg/L)			0.001	0.005	0.005	0.19	1.69	0.117	0.126	ns	2.13	0.073	0.089	ns	1.79	0.11	0.132	ns	1.89	0.13	0.127
	Thallium (mg/L)		0.0003	0.0003	0.006	0.006	0.0008	<0.006	<0.006	<0.006	ns	<0.006	<0.006	<0.006	ns	<0.0003	<0.006	<0.006	ns	<0.0003	<0.006	<0.006
	Tin (mg/L)			0.001	0.002	0.002	<0.001	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002
	Titanium (mg/L)			0.002	0.002	0.002	<0.002	0.005	<0.002	<0.002	ns	0.004	<0.002	<0.002	ns	0.004	<0.002	<0.002	ns	0.003	<0.002	<0.002
	Uranium (mg/L)	0.02	0.005	0.005	0.002	0.002	<0.005	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	ns	0.003	<0.002	<0.002
	Vanadium (mg/L)		0.006	0.001	0.002	0.002	0.009	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002
	Zinc (mg/L)	5	0.03	0.003	0.005	0.005	0.013	1.32	0.02	0.024	ns	0.498	0.008	0.009	ns	0.015	0.01	0.006	ns	0.08	0.042	0.009
Wet Chemistry	Alkalinity (CaCO3) (mg/L)	500		10	5	5	290	306	261	278	ns	264	251	266	ns	275	285	284	ns	307	300	300
	Bicarbonate (CaCO3) (mg/L)			10	5	5	289	306	261	278	ns	264	251	266	ns	275	285	284	ns	307	300	300
	Carbonate (CaCO3) (mg/L)			10	5	5	<10	<5	<5	<5	ns	<5	<5	<5	ns	<5	<5	<5	ns	<5	<5	<5
	Colour (TCU)	5		1	5	5	16	<5	<5	6	ns	<5	<5	5	ns	<5	<5	<5	ns	<5	<5	5
	Total Organic Carbon (mg/L)				0.5	0.5	na	9.9	5.4	1.4	ns	1.2	1.6	1.5	ns	12.4	5.4	2.1	ns	19.7	3	2.6
	DOC (mg/L)	5		0.7	0.5	0.5	<0.7	0.8	3.9	1.5	ns	1.2	1.5	1.3	ns	1.5	4.8	1.6	ns	2.9	3	1.5
	Hardness (CaCO3) (mg/L)	100		10	10	10	456	320	389	376	ns	261	296	293	ns	291	320	323	ns	312	323	312
	Ammonia as N (mg/L)			0.05	0.02	0.02	<0.05	<0.02	<0.02	<0.02	ns	1.05	<0.02	<0.02	ns	<0.02	<0.02	0.31	ns	<0.02	<0.02	0.05
	Conductivity (us/cm)			3	2	2	1100	1050	1110	1200	ns	547	642	623	ns	775	823	774	ns	695	728	669
	pH	8.5	6.5 - 8.5	0.1	N/A	N/A	7.5	7.82	8.01	8.07	ns	8.13	8.18	8.20	ns	7.89	8.13	8.17	ns	8.01	8.19	8.03
Calculated Values	Anion sum (meq/L)			0.01			12.1	11.6		11.9	ns	6.3	6.76	6.21	ns	7.6	9.16	7.71	ns	7.25		6.87
	Cation sum (meq/L)			0.01			12.4	10.1		12.9	ns	6.01	7.03	7.3	ns	8.22	8.75	8.91	ns	8		7.94
	% Difference (%)			0.01	0.1	0.1	2.62	6.8	2.5	0.5	ns	2.4	1.9	1.5	ns	3.9	2.3	1.5	ns	4.9	2.2	0.5
	Langelier Index			0.0001			-0.10	0.92	1.59	1.2	ns	1.14	1.19	1.23	ns	0.93	1.23	1.27	ns	1.13	1.32	1.14
	Saturation pH (pH units)			0.01			7.60	6.9	6.42	6.87	ns	6.99	6.99	6.97	ns	6.96	6.9	6.9	ns	6.88	6.87	6.89
	Silica (mg/L)				0.05	0.05	12.9	11.4	8.94	10.2	ns	8.53	3.56	8.81	ns	11.0	4.33	10.1	ns	9.93	3.82	8.44

At or Exceeds ODWQS

Hanlon Creek Business Park - Groundwater Monitoring Program

Groundwater Quality

	Parameter (units)	ODWQS	PWQO	RDL			Monitoring Wells 103								104							
				2003	2008-10	2011-14	2003	2008	2009	2010	2011	2012	2013	2014	2003	2008	2009	2010	2011	2012	2013	2014
Anions	Chloride (mg/L)	250		2.0	0.10	0.10 - 0.50	ns	143	173	237	246	212	289	301	ns	49.9	47.1	48.7	46.7	65.4	79.7	123
	Fluoride (mg/L)	1.5		0.10	0.05	0.05 - 1.25	ns	0.16	<0.05	0.11	<0.05	<0.05	<0.5	<1.25	ns	0.19	<0.05	0.09	<0.05	<0.05	<0.10	<1.25
	Nitrate as N (mg/L)	10.0		0.10	0.05	0.05 - 1.25	ns	0.27	0.14	0.23	0.2	0.26	<0.5	<1.25	ns	<0.05	<0.05	0.06	<0.05	<0.05	<0.10	<1.25
	Nitrite as N (mg/L)	1.0		0.10	0.05	0.05 - 1.25	ns	<0.05	<0.05	<0.05	<0.05	<0.05	<0.5	<1.25	ns	<0.05	<0.05	<0.05	<0.05	<0.05	<0.10	<1.25
	Phosphate-P (ortho) (mg/L)			0.30	0.10	0.10 - 2.50	ns	<0.10	<0.10	<0.10	<0.10	<0.10	<1.0	<2.50	ns	<0.10	<0.10	<0.10	<0.10	<0.10	<0.20	<2.50
	Sulphate (mg/L)	500		2.0	0.10	0.10 - 0.50	ns	37.0	18.5	19.5	23.9	41.6	60	27.4	ns	89.4	20.7	25.5	22	15.9	14.9	9.78
Metals	Aluminum (mg/L)	0.1	0.075	0.01	0.004	0.004	ns	3.29	0.009	0.006	0.012	0.024	0.006	<0.004	ns	0.630	0.005	0.005	0.072	0.008	0.007	0.005
	Antimony (mg/L)	0.006	0.02	0.005	0.006	0.003	ns	<0.006	<0.006	<0.006	<0.003	<0.003	<0.003	<0.003	ns	<0.006	<0.006	<0.006	<0.003	<0.003	<0.003	<0.003
	Arsenic (mg/L)	0.025	0.005	0.001	0.003	0.003	ns	0.028	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	ns	0.013	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Barium (mg/L)	1.0		0.01	0.002	0.002	ns	0.232	0.097	0.112	0.094	0.094	0.09	0.126	ns	0.368	0.095	0.116	0.077	0.067	0.082	0.091
	Beryllium (mg/L)		1.1	0.001	0.001	0.001	ns	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	ns	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Bismuth (mg/L)			0.001	0.002	0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Boron (mg/L)	5.0	0.2	0.05	0.010	0.010	ns	0.012	0.014	0.012	<0.010	0.01	0.011	0.013	ns	0.016	<0.010	<0.010	<0.010	<0.010	0.014	<0.010
	Cadmium (mg/L)	0.005	0.0005	0.0001	0.002	0.001	ns	0.0015	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	ns	0.0049	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Calcium (mg/L)	200		0.5	0.05	0.05	ns	91.2	109	124	103	110	110	109	ns	97.8	91.4	99.1	83	76.1	77.7	83.3
	Chromium (mg/L)	0.05	0.0089	0.001	0.003	0.003	ns	0.025	0.003	<0.003	<0.003	0.005	<0.003	<0.003	ns	0.006	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Cobalt (mg/L)		0.0009	0.0008	0.001	0.001	ns	0.013	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	ns	0.022	<0.001	0.004	<0.001	<0.001	<0.001	<0.001
	Copper (mg/L)	1.0	0.005	0.001	0.003	0.002	ns	0.097	0.005	0.005	0.005	0.004	<0.003	0.004	ns	0.167	<0.003	0.014	<0.003	<0.003	<0.003	<0.003
	Iron (mg/L)	0.3	0.3	0.05	0.010	0.010	ns	11.0	0.109	0.275	0.272	0.247	0.271	0.27	ns	12.2	1.12	0.061	0.738	0.771	1.45	1.42
	Lead (mg/L)	0.010	0.025	0.001	0.002	0.002	ns	0.149	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	ns	0.014	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Magnesium (mg/L)			0.5	0.05	0.05	ns	27.4	34.2	38.8	32.9	34	34.3	35.2	ns	30.4	28.8	31	26.4	25.2	24.2	27.7
	Manganese (mg/L)	0.05		0.001	0.002	0.002	ns	1.52	0.103	0.151	0.122	0.121	0.11	0.139	ns	3.25	0.196	0.358	0.339	0.203	0.414	0.358
	Molybdenum (mg/L)		0.04	0.001	0.002	0.001	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Nickel (mg/L)		0.025	0.002	0.003	0.003	ns	0.020	<0.003	0.006	<0.003	<0.003	<0.003	<0.003	ns	0.036	<0.003	0.009	<0.003	<0.003	<0.003	<0.003
	Phosphorus (mg/L)		0.01	0.05	0.05	0.05	ns	2.43	0.02	<0.05	<0.05	<0.05	<0.05	<0.05	ns	2.11	0.03	<0.05	<0.05	<0.05	<0.05	<0.05
	Potassium (mg/L)			0.5	0.05	0.05	ns	1.96	1.18	1.4	1.13	1.3	1.19	1.24	ns	1.72	0.67	1.02	0.67	0.88	0.87	1
	Selenium (mg/L)	0.01	0.1	0.005	0.004	0.004	ns	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	ns	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
	Silver (mg/L)		0.0001	0.0001	0.002	0.002	ns	<0.0001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	ns	<0.0001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Sodium (mg/L)	20		0.5	0.05	0.05	ns	90.4	98.4	121	121	118	134	139	ns	18.9	19.6	22.1	19.4	34.9	37	46.8
	Strontium (mg/L)			0.001	0.005	0.005	ns	0.741	0.126	0.168	0.152	0.145	0.17	0.174	ns	1.6	0.117	0.171	0.117	0.09	0.115	0.131
	Thallium (mg/L)		0.0003	0.0003	0.006	0.006	ns	<0.0003	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	ns	<0.0003	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
	Tin (mg/L)			0.001	0.002	0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Titanium (mg/L)			0.002	0.002	0.002	ns	0.046	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	ns	0.003	<0.002	<0.002	0.003	<0.002	<0.002	<0.002
	Uranium (mg/L)	0.02	0.005	0.005	0.002	0.002	ns	0.003	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Vanadium (mg/L)		0.006	0.001	0.002	0.002	ns	0.047	<0.002	0.003	<0.002	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Zinc (mg/L)	5	0.03	0.003	0.005	0.005	ns	0.983	0.013	0.02	0.013	0.035	0.009	0.014	ns	0.46	0.016	0.503	0.005	0.006	<0.005	0.006
Wet Chemistry	Alkalinity (CaCO3) (mg/L)	500		10	5	5	ns	325	381	360	327	332	305	339	ns	259	297	320	275	268	242	279
	Bicarbonate (CaCO3) (mg/L)			10	5	5	ns	325	381	360	327	332	305	339	ns	259	297	320	275	268	242	279
	Carbonate (CaCO3) (mg/L)			10	5	5	ns	<5	<5	<5	<5	<5	<5	<5	ns	<5	<5	<5	<5	<5	<5	<5
	Colour (TCU)	5		1	5	5	ns	20	34	25	29	37	13	29	ns	10	27	19	42	44	6	33
	Total Organic Carbon (mg/L)				0.5	0.5	ns	22.2	7.8	6.3	5	6.4	5	6.6	ns	22.6	11.9	11.3	5.2	6.9	6.7	6
	DOC (mg/L)	5		0.7	0.5	0.5	ns	9.0	7.5	6.6	5	4.8	3.9	6.5	ns	6.9	11.1	5.4	4.8	4.8	5.5	5.9
	Hardness (CaCO3) (mg/L)	100		10	10	10	ns	341	413	469	393	415	416	417	ns	369	347	375	316	294	294	322
	Ammonia as N (mg/L)			0.05	0.02	0.02	ns	<0.02	<0.02	<0.02	0.02	<0.02	<0.02	0.05	ns	<0.02	0.09	0.03	0.06	0.08	0.07	0.17
	Conductivity (us/cm)			3	2	2	ns	1010	1240	1300	1260	1230	1520	1570	ns	731	717	711	642	675	778	898
	pH	8.5	6.5 - 8.5	0.1	N/A	N/A	ns	7.61	7.83	7.92	7.65	8.17	7.99	7.82	ns	7.67	7.97	8.02	7.71	8.1	7.85	7.87
Calculated Values	Anion sum (meq/L)			0.01			ns	10.3		13.1	14	13.5	15.5	15.8	ns	7.61		7.26	7.28	7.54	7.4	9.25
	Cation sum (meq/L)			0.01			ns	10.8		14.7	13.1	13.5	14.2	14.4	ns	8.25		8.49	7.18	7.42	7.5	8.51
	% Difference (%)			0.01	0.1	0.1	ns	2.5	1.3	1.3	3.1	0.2	4.5	4.7	ns	4	0.7	1	0.7	0.8	0.7	4.2
	Langelier Index			0.0001			ns	0.79	1.14	1.26	0.87	1.42	1.19	1.07	ns	0.76	1.12	1.24	0.79	1.14	0.84	0.96
	Saturation pH (pH units)			0.01			ns	6.82	6.69	6.66	6.78	6.75	6.8	6.75	ns	6.91	6.85	6.78	6.92	6.96	7.01	6.91
	Silica (mg/L)				0.05	0.05	ns	9.87	4.31	11.6	10.1	4.56	10.2	10.3	ns	12.0	4.65	13.3	10.7	4.16	10.3	10.2

At or Exceeds ODWQS

Hanlon Creek Business Park - Groundwater Monitoring Program

Groundwater Quality

	Parameter (units)	ODWQS	PWQO	RDL			Monitoring Wells 105								106				107							
				2003	2008-10	2011-14	2003	2008	2009	2010	2011	2012	2013	2014	2003	2008	2009	2010	2003	2008	2009	2010	2011	2012	2013	2014
Anions	Chloride (mg/L)	250		2.0	0.10	0.10 - 0.50	ns	25.6	39.6	51.0	70.4	56.1	50.6	41.7	ns	182	288	241	ns	63.4	69.1	85.3	80.9	117	174	166
	Fluoride (mg/L)	1.5		0.10	0.05	0.05 - 1.25	ns	0.26	0.22	0.18	<0.05	<0.05	<0.25	<0.25	ns	0.05	<0.05	0.1	ns	0.06	<0.05	<0.05	<0.05	<0.05	<0.25	<0.10
	Nitrate as N (mg/L)	10.0		0.10	0.05	0.05 - 1.25	ns	<0.05	<0.05	<0.05	<0.05	<0.05	<0.25	<0.25	ns	5.20	1.94	3.6	ns	2.42	1.43	5.1	3.11	3.25	2.82	2.71
	Nitrite as N (mg/L)	1.0		0.10	0.05	0.05 - 1.25	ns	<0.05	<0.05	<0.05	<0.05	<0.05	<0.25	<0.25	ns	<0.05	1.0	<0.05	ns	<0.05	<0.05	<0.05	<0.05	<0.05	<0.25	<0.10
	Phosphate-P (ortho) (mg/L)			0.30	0.10	0.10 - 2.50	ns	<0.10	<0.10	<0.10	<0.10	<0.10	<0.50	<0.50	ns	<0.10	<0.10	<0.10	ns	<0.10	<0.10	<0.10	<0.10	<0.10	<0.50	<0.20
	Sulphate (mg/L)	500		2.0	0.10	0.10 - 0.50	ns	17.5	20.3	20.2	17.5	19.1	19.1	16.6	ns	26.5	24.4	31.1	ns	18.2	11	15.1	17.4	16.9	18.6	17.7
Metals	Aluminum (mg/L)	0.1	0.075	0.01	0.004	0.004	ns	1.31	0.013	<0.004	0.007	0.007	0.005	<0.004	ns	1.90	<0.004	<0.004	ns	1.16	0.108	<0.004	0.007	0.013	0.006	<0.004
	Antimony (mg/L)	0.006	0.02	0.005	0.006	0.003	ns	<0.006	<0.006	<0.006	<0.003	<0.003	<0.003	<0.003	ns	<0.006	<0.006	<0.006	ns	<0.006	<0.006	<0.006	<0.003	<0.003	<0.003	<0.003
	Arsenic (mg/L)	0.025	0.005	0.001	0.003	0.003	ns	0.011	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	ns	0.009	<0.003	<0.003	ns	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Barium (mg/L)	1.0		0.01	0.002	0.002	ns	0.173	0.088	0.084	0.087	0.078	0.065	0.063	ns	0.275	0.091	0.091	ns	0.429	0.081	0.082	0.054	0.075	0.064	0.075
	Beryllium (mg/L)		1.1	0.001	0.001	0.001	ns	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	ns	<0.001	<0.001	<0.001	ns	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Bismuth (mg/L)			0.001	0.002	0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Boron (mg/L)	5.0	0.2	0.05	0.010	0.010	ns	0.014	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	ns	0.021	0.013	0.012	ns	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
	Cadmium (mg/L)	0.005	0.0005	0.0001	0.002	0.001	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	ns	0.008	<0.002	<0.002	ns	0.0039	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Calcium (mg/L)	200		0.5	0.05	0.05	ns	69.7	84.5	83.4	81.3	75.4	72.6	68.9	ns	85.4	85.3	83.1	ns	76.4	84.5	93.3	71.9	80.9	86	89.7
	Chromium (mg/L)	0.05	0.0089	0.001	0.003	0.003	ns	0.004	<0.003	<0.003	<0.003	0.004	<0.003	<0.003	ns	0.009	0.003	<0.003	ns	0.012	<0.003	<0.003	<0.003	0.005	<0.003	0.006
	Cobalt (mg/L)		0.0009	0.0008	0.001	0.001	ns	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	ns	0.027	<0.001	<0.001	ns	0.013	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Copper (mg/L)	1.0	0.005	0.001	0.003	0.002	ns	0.028	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	ns	0.060	<0.003	<0.003	ns	0.075	0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Iron (mg/L)	0.3	0.3	0.05	0.010	0.010	ns	4.09	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	ns	3.92	<0.010	<0.010	ns	2.58	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
	Lead (mg/L)	0.010	0.025	0.001	0.002	0.002	ns	0.066	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	ns	0.126	<0.002	<0.002	ns	0.091	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Magnesium (mg/L)			0.5	0.05	0.05	ns	25.2	29.2	30	29.5	29.3	26.7	26.3	ns	24.4	24.6	24.5	ns	23.4	26.7	29.8	22.6	26.4	26.2	28.5
	Manganese (mg/L)	0.05		0.001	0.002	0.002	ns	1.47	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	ns	5.00	0.006	<0.002	ns	1.50	0.067	0.038	<0.002	0.005	0.003	0.004
	Molybdenum (mg/L)		0.04	0.001	0.002	0.001	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	ns	<0.002	0.002	<0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Nickel (mg/L)		0.025	0.002	0.003	0.003	ns	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	ns	0.025	<0.003	<0.003	ns	0.056	<0.003	0.004	<0.003	<0.003	<0.003	<0.003
	Phosphorus (mg/L)		0.01	0.05	0.05	0.05	ns	1.41	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	ns	3.94	<0.05	<0.05	ns	0.54	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Potassium (mg/L)			0.5	0.05	0.05	ns	1.11	0.74	0.81	0.78	0.89	0.69	0.67	ns	2.44	1.63	1.52	ns	1.76	1.33	1.08	0.81	1.22	1.3	1.41
	Selenium (mg/L)	0.01	0.1	0.005	0.004	0.004	ns	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	ns	<0.004	<0.004	<0.004	ns	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
	Silver (mg/L)		0.0001	0.0001	0.002	0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	ns	0.0001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Sodium (mg/L)	20		0.5	0.05	0.05	ns	18.9	21.8	23.3	22.5	26.7	30	27.7	ns	99.9	151	158	ns	35.1	36.2	40.2	32	61.3	73.1	77.9
	Strontium (mg/L)			0.001	0.005	0.005	ns	0.653	0.129	0.142	0.172	0.157	0.131	0.117	ns	1.26	0.117	0.134	ns	0.247	0.091	0.113	0.095	0.106	0.123	0.105
	Thallium (mg/L)		0.0003	0.0003	0.006	0.006	ns	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	ns	<0.006	<0.006	<0.006	ns	<0.0003	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
	Tin (mg/L)			0.001	0.002	0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Titanium (mg/L)			0.002	0.002	0.002	ns	0.015	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	ns	0.021	<0.002	<0.002	ns	0.073	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Uranium (mg/L)	0.02	0.005	0.005	0.002	0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Vanadium (mg/L)		0.006	0.001	0.002	0.002	ns	0.004	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	ns	0.006	<0.002	0.002	ns	0.01	<0.002	<0.002	<0.002	<0.002	0.003	<0.002
	Zinc (mg/L)	5	0.03	0.003	0.005	0.005	ns	0.201	0.028	<0.005	<0.005	0.007	0.007	<0.005	ns	1.06	0.014	0.019	ns	0.669	0.231	0.021	0.008	0.029	0.016	0.011
Wet Chemistry	Alkalinity (CaCO3) (mg/L)	500		10	5	5	ns	281	290	285	277	278	279	286	ns	263	277	293	ns	262	279	297	219	273	250	275
	Bicarbonate (CaCO3) (mg/L)			10	5	5	ns	267	290	285	277	278	279	286	ns	263	277	293	ns	262	279	297	219	266	283	275
	Carbonate (CaCO3) (mg/L)			10	5	5	ns	14	<5	<5	<5	<5	<5	<5	ns	<5	<5	<5	ns	<5	<5	<5	<5	8	<5	<5
	Colour (TCU)	5		1	5	5	ns	<5	<5	<5	<5	<5	<5	<5	ns	<5	<5	<5	ns	<5	<5	<5	<5	<5	<5	<5
	Total Organic Carbon (mg/L)				0.5	0.5	ns	1.1	1.9	1.2	1	3	1	1.7	ns	1.4	1.3	1.4	ns	5.4	2.7	1.4	0.9	3.7	2	3.2
	DOC (mg/L)	5		0.7	0.5	0.5	ns	1.1	2.2	1.2	0.9	2.9	1	1.6	ns	1.4	1.3	1.5	ns	2.6	2.8	1.4	1.1	0.9	1.8	1.8
	Hardness (CaCO3) (mg/L)	100		10	10	10	ns	278	331	332	324	309	291	280	ns	314	314	308	ns	287	321	356	273	311	323	341
	Ammonia as N (mg/L)			0.05	0.02	0.02	ns	<0.02	<0.02	<0.02	<0.02	<0.02	0.03	0.04	ns	<0.02	<0.02	<0.02	ns	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05
	Conductivity (us/cm)			3	2	2	ns	585	684	651	724	668	716	664	ns	1070	1380	1260	ns	671	733	790	685	849	1100	1050
	pH	8.5	6.5 - 8.5	0.1	N/A	N/A	ns	8.31	8.06	8.00	7.68	8.25	8.15	8.02	ns	7.99	8.13	8.13	ns	7.89	8.15	8.11	7.66	8.34	8.05	8.12
Calculated Values	Anion sum (meq/L)			0.01			ns	6.71	7.34	6.63	7.89	7.54	7.4	7.24	ns	11.3	14.4	12.6	ns	6.72	7.86	8.05	7.25	9.34	10.5	10.7
	Cation sum (meq/L)			0.01			ns	6.4	7.59	7.66	7.48	7.36	7.14	6.83	ns	10.7	12.9	13.1	ns	7.31	8.02	8.88	6.86	8.91	9.66	10.2
	% Difference (%)			0.01	0.1	0.1	ns	2.3	1.6	0.6	2.7	1.2	1.8	3	ns	2.9	5.5	1.9	ns	4.2	1	0.8	2.7	2.4	4.2	2.4
	Langelier Index			0.0001			ns	1.34	1.18	1.12	0.77	1.32	1.2	1.06	ns	1.02	1.18	1.2	ns	0.91	1.24	1.27	0.58	1.38	1.07	1.2
	Saturation pH (pH units)			0.01			ns	6.97	6.88	6.88	6.91	6.93	6.95	6.96	ns	6.97	6.95	6.93	ns	6.98	6.91	6.84	7.08	6.96	6.98	6.92
	Silica (mg/L)				0.05	0.05	ns	14.3	5.14	12.9	11.9	5.19	12.1	10.9	ns	10.5	3.69	8.51	ns	10.6	3.15	8.49	6.39	3.91	9.66	8.61

At or Exceeds ODWQS

Hanlon Creek Business Park - Groundwater Monitoring Program

Groundwater Quality

	Parameter (units)	ODWQS	PWQO	RDL			Monitoring Wells 109								110				111							
				2003	2008-10	2011-14	2003	2008	2009	2010	2011	2012	2013	2014	2003	2008	2009	2010	2003	2008	2009	2010	2011	2012	2013	2014
Anions	Chloride (mg/L)	250		2.0	0.10	0.10 - 0.50	ns	86.6	113	82.1	92.7	120	93.5	105	91.0	75.8	78.3	86.5	3.00	1.27	1.23	1.32	2.77	5.79	5.07	4.16
	Fluoride (mg/L)	1.5		0.10	0.05	0.05 - 1.25	ns	0.06	<0.05	<0.05	<0.05	<0.05	<0.25	<0.10	0.10	0.06	<0.05	<0.05	0.71	1.08	1.22	0.97	1.08	0.9	0.87	1.07
	Nitrate as N (mg/L)	10.0		0.10	0.05	0.05 - 1.25	ns	5.69	5.53	4.41	4.42	4.05	4.18	3.72	7.70	7.48	5.38	4.91	<0.10	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.25
	Nitrite as N (mg/L)	1.0		0.10	0.05	0.05 - 1.25	ns	<0.05	<0.05	<0.05	<0.05	<0.05	<0.25	<0.10	<0.10	<0.05	<0.05	<0.05	<0.10	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.25
	Phosphate-P (ortho) (mg/L)			0.30	0.10	0.10 - 2.50	ns	<0.10	<0.10	<0.10	<0.10	<0.10	<0.50	<0.20	<0.30	<0.10	<0.10	<0.10	<0.30	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.50
	Sulphate (mg/L)	500		2.0	0.10	0.10 - 0.50	ns	21.8	22.5	20.6	18.4	19.1	18.8	18.4	27.0	19.5	18.5	16.8	27.0	21.1	21	22	25.6	29.5	28.6	23
Metals	Aluminum (mg/L)	0.1	0.075	0.01	0.004	0.004	ns	1.65	<0.004	<0.004	0.008	<0.004	<0.004	<0.004	<0.01	0.981	<0.004	<0.004	0.210	0.614	<0.004	<0.004	0.007	0.087	0.005	0.011
	Antimony (mg/L)	0.006	0.02	0.005	0.006	0.003	ns	<0.006	<0.006	<0.006	<0.003	<0.003	<0.003	<0.003	<0.005	<0.006	<0.006	<0.006	<0.005	<0.006	<0.006	<0.006	<0.003	<0.003	<0.003	<0.003
	Arsenic (mg/L)	0.025	0.005	0.001	0.003	0.003	ns	0.007	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.001	<0.003	<0.003	<0.003	0.004	0.004	<0.003	<0.003	<0.003	0.004	<0.003	<0.003
	Barium (mg/L)	1.0		0.01	0.002	0.002	ns	0.309	0.094	0.095	0.085	0.086	0.089	0.083	0.10	0.126	0.086	0.084	0.08	0.093	0.067	0.064	0.071	0.089	0.072	0.056
	Beryllium (mg/L)		1.1	0.001	0.001	0.001	ns	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Bismuth (mg/L)			0.001	0.002	0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Boron (mg/L)	5.0	0.2	0.05	0.010	0.010	ns	0.016	0.011	0.011	0.012	<0.010	0.01	0.013	0.10	0.010	<0.010	<0.010	0.06	0.016	0.019	0.015	0.016	0.011	0.013	0.019
	Cadmium (mg/L)	0.005	0.0005	0.0001	0.002	0.001	ns	0.014	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.0001	0.002	<0.002	<0.002	<0.0001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Calcium (mg/L)	200		0.5	0.05	0.05	ns	94.8	112	94.4	91.3	101	81.4	95.5	91.0	81.6	91.5	93.6	53.0	43.3	57.8	55.8	53.3	56.5	56	54.4
	Chromium (mg/L)	0.05	0.0089	0.001	0.003	0.003	ns	0.006	0.004	<0.003	<0.003	0.003	<0.003	0.005	0.003	0.008	0.004	<0.003	0.002	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Cobalt (mg/L)		0.0009	0.0008	0.001	0.001	ns	0.034	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0008	0.017	<0.001	<0.001	<0.0008	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Copper (mg/L)	1.0	0.005	0.001	0.003	0.002	ns	0.058	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.001	0.026	<0.003	<0.003	<0.001	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Iron (mg/L)	0.3	0.3	0.05	0.010	0.010	ns	2.12	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.06	3.71	<0.010	<0.010	0.27	1.55	0.023	0.02	0.122	0.071	0.28	0.054
	Lead (mg/L)	0.010	0.025	0.001	0.002	0.002	ns	0.21	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	0.129	<0.002	<0.002	<0.001	0.008	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Magnesium (mg/L)			0.5	0.05	0.05	ns	27.2	32.4	27.7	27.8	30	23.6	27.7	29	25.7	28.3	29.2	23	20.8	25.1	25.2	24	25.9	25.7	24.4
	Manganese (mg/L)	0.05		0.001	0.002	0.002	ns	3.74	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.075	0.843	<0.002	<0.002	0.024	0.051	0.006	0.005	0.010	0.018	0.011	0.006
	Molybdenum (mg/L)		0.04	0.001	0.002	0.001	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.006	<0.002	<0.002	<0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Nickel (mg/L)		0.025	0.002	0.003	0.003	ns	<0.003	<0.003	0.004	<0.003	<0.003	<0.003	<0.003	0.002	0.010	<0.003	0.017	<0.002	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Phosphorus (mg/L)		0.01	0.05	0.05	0.05	ns	1.69	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.36	<0.05	<0.05	<0.05	0.16	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Potassium (mg/L)			0.5	0.05	0.05	ns	2.36	1.61	1.73	1.8	1.81	1.42	1.99	2.7	2.87	1.92	2.12	1.2	0.84	1.41	1.37	1.33	1.31	1.46	1.34
	Selenium (mg/L)	0.01	0.1	0.005	0.004	0.004	ns	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
	Silver (mg/L)		0.0001	0.0001	0.002	0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.0001	<0.002	<0.002	<0.002	<0.0001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Sodium (mg/L)	20		0.5	0.05	0.05	ns	30.9	39.0	35.2	37.8	48.9	36.4	46.9	27	34.4	34.4	37.4	5.2	10.2	3.80	4.51	3.9	4.79	5.17	5.27
	Strontium (mg/L)			0.001	0.005	0.005	ns	1.12	0.123	0.123	0.119	0.11	0.117	0.111	0.19	0.234	0.115	0.107	0.16	0.205	0.134	0.146	0.172	0.161	0.144	0.132
	Thallium (mg/L)		0.0003	0.0003	0.006	0.006	ns	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.0003	<0.006	<0.006	<0.006	<0.0003	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
	Tin (mg/L)			0.001	0.002	0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.006	0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Titanium (mg/L)			0.002	0.002	0.002	ns	0.019	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.067	<0.002	<0.002	0.009	0.034	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Uranium (mg/L)	0.02	0.005	0.005	0.002	0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.005	<0.002	<0.002	<0.002	<0.005	0.004	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Vanadium (mg/L)		0.006	0.001	0.002	0.002	ns	0.004	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.008	0.004	<0.002	<0.002	0.004	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Zinc (mg/L)	5	0.03	0.003	0.005	0.005	ns	1.15	0.019	0.017	0.016	0.016	0.02	0.019	0.011	0.521	0.021	0.024	0.008	0.015	<0.005	<0.005	<0.005	0.106	0.007	<0.005
Wet Chemistry	Alkalinity (CaCO3) (mg/L)	500		10	5	5	ns	279	279	278	266	295	284	301	270	277	266	277	240	225	218	219	216	225	219	218
	Bicarbonate (CaCO3) (mg/L)			10	5	5	ns	279	279	278	266	295	284	301	269	277	266	277	239	225	213	219	216	225	219	218
	Carbonate (CaCO3) (mg/L)			10	5	5	ns	<5	<5	<5	<5	<5	<5	<5	<10	<5	<5	<5	<10	<5	5	<5	<5	<5	<5	<5
	Colour (TCU)	5		1	5	5	ns	<5	<5	<5	<5	<5	<5	<5	<1	<5	<5	<5	65	<5	<5	<5	<5	<5	<5	<5
	Total Organic Carbon (mg/L)				0.5	0.5	ns	1.2	3.2	0.9	0.7	1.4	0.9	4	na	2.9	1.3	1.7	na	1.5	0.7	0.7	0.6	3.5	11	0.9
	DOC (mg/L)	5		0.7	0.5	0.5	ns	1.2	2.4	0.9	0.6	1	0.7	3.6	<0.7	1.0	1.1	1.6	540	0.8	0.6	0.9	0.6	0.9	11	0.9
	Hardness (CaCO3) (mg/L)	100		10	10	10	ns	349	413	350	342	376	300	353	347	310	345	354	227	194	248	243	232	248	246	236
	Ammonia as N (mg/L)			0.05	0.02	0.02	ns	0.15	<0.02	<0.02	<0.02	<0.02	<0.02	0.04	<0.05	<0.02	<0.02	<0.02	0.08	<0.02	<0.02	<0.02	<0.02	<0.02	0.08	0.03
	Conductivity (us/cm)			3	2	2	ns	579	899	771	770	901	862	939	860	758	817	771	450	416	437	415	441	451	483	469
	pH	8.5	6.5 - 8.5	0.1	N/A	N/A	ns	8.03	7.83	8.09	7.74	8.25	8.16	8.07	7.7	7.93	7.89	8.08	7.8	8.09	8.34	8.14	7.87	8.17	8.19	8.03
Calculated Values	Anion sum (meq/L)			0.01			ns	8.88		7.71	8.63	9.97	9.01	9.63	9.08	8.62		7.77	5.49	4.97	4.83	4.21	4.99	5.32	5.16	5.01
	Cation sum (meq/L)			0.01			ns	8.38		8.57	8.53	9.68	7.62	9.14	8.17	7.76		8.75	4.80	4.33	5.15	5.09	4.84	5.19	5.17	4.99
	% Difference (%)			0.01	0.1	0.1	ns	2.9	1.8	0.3	0.6	1.5	8.3	2.6	-10.55	5.3	0.8	0.4	-13.41	6.9	3.2	1.6	1.5	1.3	0.1	0.3
	Langelier Index			0.0001			ns	1.16	1.19	1.22	0.84	1.4	1.23	1.24	0.02	1	1.15	1.21	-0.10	0.90	1.24	1.04	0.74	1.09	1.09	0.91
	Saturation pH (pH units)			0.01			ns	6.87	6.64	6.87	6.9	6.85	6.93	6.83	7.68	6.93	6.74	6.87	7.90	7.19	7.1	7.1	7.13	7.08	7.1	7.12
	Silica (mg/L)				0.05	0.05	ns	11.3	4.6	10.1	9.96	4.21	10.8	10.1	11.3	11.5	4.65	12.1	18.4	18.4	7.86	16.8	17.1	6.93	19.1	15.9

At or Exceeds ODWQS

Hanlon Creek Business Park - Groundwater Monitoring Program

Groundwater Quality

	Parameter (units)	ODWQS	PWQO	RDL			Monitoring Wells 112								113				114			
				2003	2008-10	2011-14	2003	2008	2009	2010	2011	2012	2013	2014	2003	2008	2009	2010	2003	2008	2009	2010
Anions	Chloride (mg/L)	250		2.0	0.10	0.10 - 0.50	<2.0	1.88	1.92	1.66	2.57	2.93	3.1	3.1	2.30	0.88	0.82	0.71	5.40	0.55	0.42	0.58
	Fluoride (mg/L)	1.5		0.10	0.05	0.05 - 1.25	0.67	0.73	0.8	0.67	0.7	0.82	0.61	0.68	0.68	1.33	1.4	1.14	0.82	0.77	0.81	0.7
	Nitrate as N (mg/L)	10.0		0.10	0.05	0.05 - 1.25	<0.10	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.25	<0.10	<0.05	<0.05	<0.05	0.13	<0.05	<0.05	<0.05
	Nitrite as N (mg/L)	1.0		0.10	0.05	0.05 - 1.25	<0.10	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.25	<0.10	<0.05	<0.05	<0.05	<0.10	<0.05	<0.05	<0.05
	Phosphate-P (ortho) (mg/L)			0.30	0.10	0.10 - 2.50	<0.30	<0.10	<0.10	<0.10	<0.10	0.16	<0.10	<0.50	<0.30	<0.10	0.37	<0.10	<0.30	<0.10	0.64	<0.10
	Sulphate (mg/L)	500		2.0	0.10	0.10 - 0.50	15.0	16.4	18.1	12.2	20.6	22.5	21.9	22.7	34.0	19.5	20.3	20.3	70.0	4.54	4.73	5.48
Metals	Aluminum (mg/L)	0.1	0.075	0.01	0.004	0.004	<0.01	0.041	0.005	<0.004	0.007	0.006	0.007	<0.004	<0.01	0.145	0.011	<0.004	<0.01	0.046	0.004	<0.004
	Antimony (mg/L)	0.006	0.02	0.005	0.006	0.003	<0.005	<0.006	<0.006	<0.006	<0.003	<0.003	<0.003	<0.003	<0.005	<0.006	<0.006	<0.006	<0.005	<0.006	<0.006	<0.006
	Arsenic (mg/L)	0.025	0.005	0.001	0.003	0.003	0.003	0.004	0.005	0.004	0.005	0.005	0.004	0.004	0.005	<0.003	<0.003	<0.003	0.001	0.008	0.008	0.007
	Barium (mg/L)	1.0		0.01	0.002	0.002	0.01	0.038	0.041	0.041	0.038	0.036	0.037	0.033	0.09	0.082	0.082	0.082	0.08	0.050	0.056	0.064
	Beryllium (mg/L)		1.1	0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Bismuth (mg/L)			0.001	0.002	0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.002
	Boron (mg/L)	5.0	0.2	0.05	0.010	0.010	<0.05	0.037	0.039	0.043	0.043	0.039	0.038	0.042	<0.05	<0.010	<0.010	<0.010	<0.05	0.016	0.017	0.015
	Cadmium (mg/L)	0.005	0.0005	0.0001	0.002	0.001	<0.0001	<0.002	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.0001	<0.002	<0.002	<0.002	<0.0001	<0.002	<0.002	<0.002
	Calcium (mg/L)	200		0.5	0.05	0.05	28.0	22.9	32	27	28.7	28.7	31.8	31	59.0	51.6	59.9	62	25.0	40.8	49.5	53.9
	Chromium (mg/L)	0.05	0.0089	0.001	0.003	0.003	0.002	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.002	<0.003	<0.003	<0.003	0.002	<0.003	<0.003	<0.003
	Cobalt (mg/L)		0.0009	0.0008	0.001	0.001	<0.0008	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.0018	<0.001	<0.001	<0.001	0.0016	<0.001	<0.001	<0.001
	Copper (mg/L)	1.0	0.005	0.001	0.003	0.002	<0.001	<0.003	<0.003	<0.003	<0.003	<0.002	<0.003	<0.003	<0.001	<0.003	<0.003	<0.003	<0.001	<0.003	<0.003	<0.003
	Iron (mg/L)	0.3	0.3	0.05	0.010	0.010	<0.05	0.149	0.120	0.073	0.117	0.118	0.077	0.098	0.07	0.400	0.162	0.184	0.06	1.32	1.09	1.27
	Lead (mg/L)	0.010	0.025	0.001	0.002	0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	0.035	<0.002	<0.002	<0.001	<0.002	<0.002	<0.002
	Magnesium (mg/L)			0.5	0.05	0.05	22	22.7	27.9	25.1	25.2	25	26.9	26.7	22	21	23.6	24.6	18	20.3	23.1	25.3
	Manganese (mg/L)	0.05		0.001	0.002	0.002	0.034	0.039	0.031	0.029	0.031	0.032	0.030	0.03	0.029	0.028	0.004	0.002	0.097	0.004	0.003	0.003
	Molybdenum (mg/L)		0.04	0.001	0.002	0.001	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.001	<0.002	<0.002	<0.002	0.016	0.002	0.002	0.002
	Nickel (mg/L)		0.025	0.002	0.003	0.003	<0.002	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.002	<0.003	<0.003	<0.003	0.003	<0.003	<0.003	<0.003
	Phosphorus (mg/L)		0.01	0.05	0.05	0.05	<0.05	0.06	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.07	<0.05	<0.05	<0.05	0.05	0.06	<0.05
	Potassium (mg/L)			0.5	0.05	0.05	0.9	0.96	0.81	0.91	0.84	0.72	0.8	0.78	1.0	1.06	0.94	0.98	1.0	1	0.83	0.95
	Selenium (mg/L)	0.01	0.1	0.005	0.004	0.004	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004	<0.004
	Silver (mg/L)		0.0001	0.0001	0.002	0.002	<0.0001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.0001	<0.002	<0.002	<0.002	<0.0001	<0.002	<0.002	<0.002
	Sodium (mg/L)	20		0.5	0.05	0.05	11	12.1	12.5	14.5	11.5	11.9	12.1	12.7	4.2	3.64	3.00	3.47	34	6.55	5.08	4.83
	Strontium (mg/L)			0.001	0.005	0.005	0.38	0.426	0.361	0.41	0.436	0.373	0.395	0.363	0.30	0.193	0.172	0.169	16	0.361	0.289	0.325
	Thallium (mg/L)		0.0003	0.0003	0.006	0.006	<0.0003	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.0003	<0.006	<0.006	<0.006	<0.0003	<0.006	<0.006	<0.006
	Tin (mg/L)			0.001	0.002	0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.002
	Titanium (mg/L)			0.002	0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.009	<0.002	<0.002	<0.002	0.002	<0.002	<0.002
	Uranium (mg/L)	0.02	0.005	0.005	0.002	0.002	<0.005	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.005	<0.002	<0.002	<0.002	<0.005	<0.002	<0.002	<0.002
	Vanadium (mg/L)		0.006	0.001	0.002	0.002	0.004	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.005	<0.002	<0.002	<0.002	0.005	<0.002	<0.002	<0.002
	Zinc (mg/L)	5	0.03	0.003	0.005	0.005	0.004	0.015	0.009	0.01	0.01	0.013	0.01	0.008	0.006	0.008	0.019	<0.005	0.007	0.014	0.007	0.013
Wet Chemistry	Alkalinity (CaCO3) (mg/L)	500		10	5	5	200	185	193	180	181	189	186	186	240	228	234	228	220	226	222	226
	Bicarbonate (CaCO3) (mg/L)			10	5	5	199	185	193	180	181	189	186	186	239	228	234	228	220	226	222	226
	Carbonate (CaCO3) (mg/L)			10	5	5	<10	<5	<5	<5	<5	<5	<5	<5	<10	<5	<5	<5	<10	<5	<5	<5
	Colour (TCU)	5		1	5	5	79	<5	<5	6	<5	<5	<5	<5	4	<5	<5	<5	85	<5	<5	<5
	Total Organic Carbon (mg/L)				0.5	0.5	na	0.6	0.7	1.1	0.6	4	1.1	0.7	na	0.7	0.6	0.9	na	1.2	1.1	2
	DOC (mg/L)	5		0.7	0.5	0.5	46.0	0.5	0.7	1	0.6	1.7	0.7	0.7	56.0	0.6	0.7	0.8	51.0	1.2	1.2	1.6
	Hardness (CaCO3) (mg/L)	100		10	10	10	161	151	195	171	175	175	190	187	238	215	247	256	137	185	219	239
	Ammonia as N (mg/L)			0.05	0.02	0.02	0.33	0.37	0.07	0.13	0.2	0.13	0.16	0.3	0.06	<0.02	<0.02	0.02	0.15	0.67	0.45	0.24
	Conductivity (us/cm)			3	2	2	380	358	379	335	374	374	416	403	480	402	450	426	530	383	413	390
	pH	8.5	6.5 - 8.5	0.1	N/A	N/A	7.7	8.13	8.21	8.26	8.15	8.11	8.12	8.11	7.8	8.05	8.12	8.14	7.2	8.07	8.10	8.21
Calculated Values	Anion sum (meq/L)			0.01			4.41	4.09		3.35	4.16	4.37	4.3	4.32	5.62	4.99		4.31	6.06	4.63		3.95
	Cation sum (meq/L)			0.01			3.73	3.58		4.07	4.04	4.03	4.35	4.33	4.97	4.49		5.29	4.24	4.06		5.02
	% Difference (%)			0.01	0.1	0.1	-16.71	6.7	1.9	1.7	1.5	4.1	0.7	0.2	-12.28	5.3	0.4	2.2	-35.34	6.5	1	3.4
	Langelier Index			0.0001			-0.54	0.75	1.09	0.92	0.82	0.8	0.84	0.82	-0.06	0.91	1.18	1.08	-1.07	0.86	1.09	1.11
	Saturation pH (pH units)			0.01			8.24	7.38	7.12	7.34	7.33	7.31	7.28	7.29	7.86	7.14	6.94	7.06	8.27	7.21	7.01	7.1
	Silica (mg/L)				0.05	0.05	12.8	14.7	6.56	12.8	14.2	13.5	16	13.2	18.0	18.5	7.96	17.2	11.3	17.3	7.38	9.31

At or Exceeds ODWQS

Hanlon Creek Business Park - Groundwater Monitoring Program

Groundwater Quality

	Parameter (units)	ODWQS	PWQO	RDL			Monitoring Wells															
							115								115A							
				2003	2008-10	2011-14	2003	2008	2009	2010	2011	2012	2013	2014	2003	2008	2009	2010	2011	2012	2013	2014
Anions	Chloride (mg/L)	250		2.0	0.10	0.10 - 0.50	6.80	2.33	2.42	2.72	3.23	3.27	2.96	2.95	150	237	156	72.4	135	137	223	199
	Fluoride (mg/L)	1.5		0.10	0.05	0.05 - 1.25	0.34	0.38	0.38	0.3	0.34	0.31	0.3	0.28	<0.10	0.05	<0.05	<0.05	<0.05	<0.05	<0.25	<1.25
	Nitrate as N (mg/L)	10.0		0.10	0.05	0.05 - 1.25	<0.10	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.25	9.10	2.12	1.3	1.28	0.88	1.96	0.5	<1.25
	Nitrite as N (mg/L)	1.0		0.10	0.05	0.05 - 1.25	<0.10	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.25	<0.10	<0.05	<0.05	<0.05	<0.05	<0.05	<0.25	<1.25
	Phosphate-P (ortho) (mg/L)			0.30	0.10	0.10 - 2.50	<0.30	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.50	<0.30	<0.10	<0.10	<0.10	<0.10	<0.10	<0.50	<2.50
	Sulphate (mg/L)	500		2.0	0.10	0.10 - 0.50	45.0	30.9	32.1	31.8	33.3	34.4	32.5	32.7	29.0	22.7	14.8	11.9	13.7	24.8	18.8	15.6
Metals	Aluminum (mg/L)	0.1	0.075	0.01	0.004	0.004	<0.01	0.031	0.004	0.006	0.077	0.006	0.007	<0.004	<0.01	2.41	0.012	<0.004	0.01	0.022	0.005	<0.004
	Antimony (mg/L)	0.006	0.02	0.005	0.006	0.003	<0.005	<0.006	<0.006	<0.006	<0.003	<0.003	<0.003	<0.003	<0.005	<0.006	<0.006	<0.006	<0.003	<0.003	<0.003	<0.003
	Arsenic (mg/L)	0.025	0.005	0.001	0.003	0.003	<0.001	0.013	0.005	0.004	0.006	0.005	0.004	0.004	<0.001	0.013	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Barium (mg/L)	1.0		0.01	0.002	0.002	0.12	0.957	0.113	0.09	0.093	0.084	0.084	0.069	0.08	0.191	0.057	0.043	0.05	0.045	0.053	0.047
	Beryllium (mg/L)		1.1	0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Bismuth (mg/L)			0.001	0.002	0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Boron (mg/L)	5.0	0.2	0.05	0.010	0.010	0.11	0.020	0.012	0.01	0.013	0.011	0.011	0.013	<0.05	0.018	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
	Cadmium (mg/L)	0.005	0.0005	0.0001	0.002	0.001	<0.0001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.0001	0.007	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Calcium (mg/L)	200		0.5	0.05	0.05	63.0	52.7	57.4	57.2	56.1	55.9	56.5	53.9	110	109	93.4	83.1	95.9	77.9	98.9	83.2
	Chromium (mg/L)	0.05	0.0089	0.001	0.003	0.003	0.002	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.004	0.010	0.003	<0.003	<0.003	0.006	<0.003	<0.003
	Cobalt (mg/L)		0.0009	0.0008	0.001	0.001	<0.0008	0.009	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0008	0.023	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Copper (mg/L)	1.0	0.005	0.001	0.003	0.002	<0.001	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.001	0.082	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Iron (mg/L)	0.3	0.3	0.05	0.010	0.010	<0.05	3.25	0.176	0.246	0.51	0.397	0.314	0.347	0.08	3.68	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
	Lead (mg/L)	0.010	0.025	0.001	0.002	0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	0.208	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Magnesium (mg/L)			0.5	0.05	0.05	21	22.6	24.2	24.2	24	24.1	23.5	23.4	28	29.8	26.5	22.5	27.4	21.9	27.5	24.1
	Manganese (mg/L)	0.05		0.001	0.002	0.002	0.047	4.94	0.01	0.011	0.031	0.012	0.012	0.011	<0.001	3.19	0.002	<0.002	<0.002	0.004	<0.002	<0.002
	Molybdenum (mg/L)		0.04	0.001	0.002	0.001	0.009	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Nickel (mg/L)		0.025	0.002	0.003	0.003	<0.002	0.013	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.002	0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Phosphorus (mg/L)		0.01	0.05	0.05	0.05	<0.05	0.1	<0.05	<0.050	<0.05	<0.05	<0.05	<0.05	<0.05	9.2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Potassium (mg/L)			0.5	0.05	0.05	2.2	2.04	1.17	1.15	1.04	1.09	1.04	0.9	1.4	1.68	0.94	0.99	0.83	0.78	0.95	0.89
	Selenium (mg/L)	0.01	0.1	0.005	0.004	0.004	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
	Silver (mg/L)		0.0001	0.0001	0.002	0.002	<0.0001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.0001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Sodium (mg/L)	20		0.5	0.05	0.05	7.6	4.56	4.54	5.4	4.69	4.68	4.44	4.76	53	79.7	111	77.3	77.1	82.4	92.1	147
	Strontium (mg/L)			0.001	0.005	0.005	0.25	2.41	0.123	0.13	0.164	0.14	0.128	0.119	0.16	1.16	0.114	0.11	0.14	0.115	0.145	0.112
	Thallium (mg/L)		0.0003	0.0003	0.006	0.006	<0.0003	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.0003	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
	Tin (mg/L)			0.001	0.002	0.002	0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Titanium (mg/L)			0.002	0.002	0.002	<0.002	0.003	<0.002	<0.002	0.004	<0.002	<0.002	<0.002	<0.002	0.019	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Uranium (mg/L)	0.02	0.005	0.005	0.002	0.002	<0.005	0.004	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.005	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Vanadium (mg/L)		0.006	0.001	0.002	0.002	0.008	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.009	0.011	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Zinc (mg/L)	5	0.03	0.003	0.005	0.005	0.025	0.055	0.005	0.007	0.007	<0.005	<0.005	<0.005	0.011	0.49	0.007	0.008	<0.005	0.028	<0.005	<0.005
Wet Chemistry	Alkalinity (CaCO3) (mg/L)	500		10	5	5	230	214	206	205	213	212	208	210	270	251	351	359	335	278	303	358
	Bicarbonate (CaCO3) (mg/L)			10	5	5	229	200	206	205	213	212	208	210	269	251	351	359	335	278	303	358
	Carbonate (CaCO3) (mg/L)			10	5	5	<10	14	<5	<5	<5	<5	<5	<5	<10	<5	<5	<5	<5	<5	<5	<5
	Colour (TCU)	5		1	5	5	15	<5	<5	<5	<5	<5	<5	<5	<1	<5	<5	<5	<5	<5	<5	<5
	Total Organic Carbon (mg/L)				0.5	0.5	na	0.8	12.9	2.1	2.6	25	2	1.5	na	3.8	2	2.3	1.1	3.9	2	1.6
	DOC (mg/L)	5		0.7	0.5	0.5	2.2	0.8	12.3	1.2	2.6	3	2	1.5	1.3	3.8	2	2.1	1	2.9	2	1.6
	Hardness (CaCO3) (mg/L)	100		10	10	10	244	225	243	242	239	239	238	231	390	395	342	300	352	285	360	307
	Ammonia as N (mg/L)			0.05	0.02	0.02	0.07	<0.02	<0.02	0.02	0.06	0.04	0.08	0.06	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
	Conductivity (us/cm)			3	2	2	470	425	441	412	419	427	464	460	1000	1160	1130	807	963	910	1280	1310
	pH	8.5	6.5 - 8.5	0.1	N/A	N/A	7.7	8.32	8.21	8.16	7.95	8.21	8.04	8.07	7.5	8.27	8.02	8.08	7.71	8.01	8.12	8.2
Calculated Values	Anion sum (meq/L)			0.01			5.75	4.99	4.86	4.18	5.06	5.06	4.94	4.98	10.9	12.3	11.8	8.38	10.9	10.1	12.8	13.1
	Cation sum (meq/L)			0.01			5.26	4.74	5.08	5.11	5.01	5	4.98	4.85	10.1	11.4	11.7	9.39	10.4	9.29	11.2	12.5
	% Difference (%)			0.01	0.1	0.1	-8.90	2.6	2.3	2.6	0.5	0.6	0.4	1.3	-7.13	3.9	0.5	0.9	2.1	4.1	6.5	2.1
	Langelier Index			0.0001			-0.15	1.17	1.08	1.03	0.83	1.08	0.9	0.93	-0.13	1.38	1.21	1.25	0.89	1.05	1.27	1.35
	Saturation pH (pH units)			0.01			7.85	7.15	7.13	7.13	7.12	7.13	7.14	7.14	7.63	6.89	6.81	6.83	6.82	6.96	6.85	6.85
	Silica (mg/L)				0.05	0.05	6.67	17.6	8.38	17.5	18.3	7.45	20.4	17.5	10.6	6.41	3.25	8.72	7.06	2.94	7.44	6.83

At or Exceeds ODWQS

Hanlon Creek Business Park - Groundwater Monitoring Program

Groundwater Quality

	Parameter (units)	ODWQS	PWQO	RDL			Monitoring Wells															
							116								116A							
				2003	2008-10	2011-14	2003	2008	2009	2010	2011	2012	2013	2014	2003	2008	2009	2010	2011	2012	2013	2014
Anions	Chloride (mg/L)	250		2.0	0.10	0.10 - 0.50	68.0	27.2	31.3	29.3	35.6	36.9	46.4	56.8	15.0	13.1	9.23	13.9	13	33.2	44.8	43.9
	Fluoride (mg/L)	1.5		0.10	0.05	0.05 - 1.25	<0.10	0.15	0.11	0.12	<0.05	0.17	<0.25	<1.25	<0.10	0.12	<0.05	0.08	0.12	0.09	<0.25	<1.25
	Nitrate as N (mg/L)	10.0		0.10	0.05	0.05 - 1.25	2.30	0.12	0.08	<0.05	0.1	<0.05	<0.25	<1.25	0.54	0.10	<0.05	<0.05	0.06	0.33	0.36	<1.25
	Nitrite as N (mg/L)	1.0		0.10	0.05	0.05 - 1.25	0.45	<0.05	<0.05	<0.05	<0.05	<0.05	<0.25	<1.25	<0.10	<0.05	<0.05	<0.05	<0.05	<0.05	<0.25	<1.25
	Phosphate-P (ortho) (mg/L)			0.30	0.10	0.10 - 2.50	<0.30	<0.10	<0.10	<0.10	<0.10	<0.10	<0.50	<2.50	<0.30	<0.10	<0.10	<0.10	<0.10	<0.10	<0.50	<2.50
	Sulphate (mg/L)	500		2.0	0.10	0.10 - 0.50	57.0	33.6	24.1	23.5	16.9	21.5	20.7	20.4	57.0	25.4	8.82	10.2	15.7	16.9	14.6	7.92
Metals	Aluminum (mg/L)	0.1	0.075	0.01	0.004	0.004	<0.01	3.20	0.006	<0.004	0.007	0.03	0.004	<0.004	<0.01	1.84	<0.004	0.016	0.008	0.007	<0.004	0.189
	Antimony (mg/L)	0.006	0.02	0.005	0.006	0.003	<0.005	<0.006	<0.006	<0.006	<0.003	<0.003	<0.003	<0.003	<0.005	<0.006	<0.006	<0.006	<0.003	<0.003	<0.003	<0.003
	Arsenic (mg/L)	0.025	0.005	0.001	0.003	0.003	0.001	0.004	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.002	0.007	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Barium (mg/L)	1.0		0.01	0.002	0.002	0.06	0.170	0.039	0.052	0.037	0.047	0.068	0.043	0.04	0.122	0.031	0.041	0.044	0.044	0.036	0.041
	Beryllium (mg/L)		1.1	0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Bismuth (mg/L)			0.001	0.002	0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Boron (mg/L)	5.0	0.2	0.05	0.010	0.010	0.09	0.011	0.013	<0.010	<0.010	0.011	<0.010	0.013	<0.05	0.011	<0.010	<0.010	0.019	<0.010	<0.010	0.011
	Cadmium (mg/L)	0.005	0.0005	0.0001	0.002	0.001	<0.0001	0.0027	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.0001	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Calcium (mg/L)	200		0.5	0.05	0.05	94.0	81.1	90.6	82.2	88.8	85.2	97.1	94.7	84.0	74.6	84.8	94.9	66.3	94.7	98.4	93
	Chromium (mg/L)	0.05	0.0089	0.001	0.003	0.003	0.003	0.015	<0.003	<0.003	<0.003	0.003	<0.003	<0.003	0.003	0.012	<0.003	<0.003	<0.003	0.003	<0.003	<0.003
	Cobalt (mg/L)		0.0009	0.0008	0.001	0.001	0.0008	0.012	<0.001	0.001	<0.001	<0.001	0.002	<0.001	<0.0008	0.012	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Copper (mg/L)	1.0	0.005	0.001	0.003	0.002	0.002	0.057	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.002	0.136	<0.003	0.003	<0.003	<0.003	<0.003	0.005
	Iron (mg/L)	0.3	0.3	0.05	0.010	0.010	0.06	7.45	<0.010	<0.010	1.62	<0.010	<0.010	<0.010	0.05	5.07	0.265	<0.010	<0.010	0.038	0.300	1.35
	Lead (mg/L)	0.010	0.025	0.001	0.002	0.002	<0.001	0.114	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	0.154	<0.002	<0.002	<0.002	<0.002	<0.002	0.007
	Magnesium (mg/L)			0.5	0.05	0.05	34	25.7	27.5	26.4	29.1	27.4	30.7	31.1	22	22.5	24.7	28.4	19	31.3	32.1	29.9
	Manganese (mg/L)	0.05		0.001	0.002	0.002	0.14	1.66	0.002	0.386	0.069	0.042	1.97	0.148	0.021	1.11	0.078	0.046	0.044	0.055	0.062	0.127
	Molybdenum (mg/L)		0.04	0.001	0.002	0.001	0.009	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.003	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Nickel (mg/L)		0.025	0.002	0.003	0.003	0.002	0.017	<0.003	0.004	<0.003	<0.003	<0.003	<0.003	<0.002	0.030	<0.003	0.003	<0.003	<0.003	<0.003	<0.003
	Phosphorus (mg/L)		0.01	0.05	0.05	0.05	<0.05	0.97	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.6	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Potassium (mg/L)			0.5	0.05	0.05	2.7	1.58	1.57	1.2	0.74	1.28	1.42	1.18	1.0	0.9	0.69	0.81	1.87	0.75	0.76	0.7
	Selenium (mg/L)	0.01	0.1	0.005	0.004	0.004	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
	Silver (mg/L)		0.0001	0.0001	0.002	0.002	<0.0001	<0.0001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.0001	<0.0001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Sodium (mg/L)	20		0.5	0.05	0.05	25	13	16.5	16.4	11.8	14.1	17.2	22.0	5.8	7.69	7.97	8.20	10.30	16.00	20.70	30.2
	Strontium (mg/L)			0.001	0.005	0.005	0.21	0.419	0.106	0.16	0.12	0.117	0.158	0.115	0.12	0.467	0.095	0.118	0.11	0.134	0.141	0.125
	Thallium (mg/L)		0.0003	0.0003	0.006	0.006	<0.0003	<0.0003	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.0003	<0.0003	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
	Tin (mg/L)			0.001	0.002	0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Titanium (mg/L)			0.002	0.002	0.002	<0.002	0.081	<0.002	<0.002	<0.002	0.002	<0.002	<0.002	<0.002	0.059	<0.002	<0.002	<0.002	<0.002	<0.002	0.013
	Uranium (mg/L)	0.02	0.005	0.005	0.002	0.002	<0.005	0.002	<0.002	<0.002	<0.002	0.002	<0.002	0.002	<0.005	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Vanadium (mg/L)		0.006	0.001	0.002	0.002	0.009	0.023	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.008	0.021	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Zinc (mg/L)	5	0.03	0.003	0.005	0.005	0.019	0.649	0.020	0.038	<0.005	0.021	0.02	0.025	0.031	0.467	0.012	0.052	0.008	0.009	0.017	0.032
Wet Chemistry	Alkalinity (CaCO3) (mg/L)	500		10	5	5	280	276	298	280	307	292	295	314	250	262	268	336	228	341	323	356
	Bicarbonate (CaCO3) (mg/L)			10	5	5	279	276	268	280	307	292	295	314	249	262	268	336	228	341	323	356
	Carbonate (CaCO3) (mg/L)			10	5	5	<10	<5	<5	<5	<5	<5	<5	<5	<10	<5	<5	<5	<5	<5	<5	<5
	Colour (TCU)	5		1	5	5	18	<5	<5	5	<5	<5	<5	<5	11	<5	<5	<5	<5	<5	<5	<5
	Total Organic Carbon (mg/L)				0.5	0.5	na	6.3	7.5	5	1.6	14.4	2.9	2.2	na	8.2	3.1	9.2	2.3	22.2	3.2	3.7
	DOC (mg/L)	5		0.7	0.5	0.5	6.6	2.4	4.4	2	1.5	7	2.5	2.1	1.9	3.0	3.1	2.5	2.3	2.2	1.9	2.5
	Hardness (CaCO3) (mg/L)	100		10	10	10	375	308	339	314	342	326	369	365	300	279	313	354	244	365	378	355
	Ammonia as N (mg/L)			0.05	0.02	0.02	<0.05	<0.02	<0.02	0.56	<0.02	0.02	<0.02	0.03	<0.05	<0.02	<0.02	0.09	<0.02	<0.02	<0.02	0.06
	Conductivity (us/cm)			3	2	2	830	604	624	589	629	635	726	818	600	526	524	615	471	700	759	826
	pH	8.5	6.5 - 8.5	0.1	N/A	N/A	7.6	7.66	7.84	8.00	7.68	8.11	8.03	8.12	7.5	7.63	7.98	7.93	8.05	8.01	8.08	8.01
Calculated Values	Anion sum (meq/L)			0.01			8.87	6.1	6.76	6	7.5	7.34	7.64	8.31	6.65	5.29	5.80	6.23	5.26	8.14	8.05	8.52
	Cation sum (meq/L)			0.01			8.65	6.77	7.54	7.06	7.36	7.15	8.16	8.27	6.28	5.93	6.63	7.46	5.37	8.02	8.47	8.44
	% Difference (%)			0.01	0.1	0.1	-2.51	5.2	5.5	1	1	1.3	3.3	0.2	-5.72	5.7	6.6	0.9	1	0.8	2.5	0.5
	Langelier Index			0.0001			-0.06	0.73	0.94	1.08	0.84	1.23	1.21	1.32	-0.21	0.63	1.07	1.15	0.96	1.25	1.31	1.25
	Saturation pH (pH units)			0.01			7.66	6.93	6.90	6.92	6.84	6.88	6.82	6.8	7.71	7.0	6.91	6.78	7.09	6.76	6.77	6.76
	Silica (mg/L)				0.05	0.05	10.5	9.79	3.99	8.88	7.21	3.55	9.31	8.43	7.90	8.38	3.41	8.06	8.01	3.67	8.45	8.0

At or Exceeds ODWQS

Hanlon Creek Business Park - Groundwater Monitoring Program

Groundwater Quality

	Parameter (units)	ODWQS	PWQO	RDL			Monitoring Wells 117								117A							
				2003	2008-10	2011-14	2003	2008	2009	2010	2011	2012	2013	2014	2003	2008	2009	2010	2011	2012	2013	2014
Anions	Chloride (mg/L)	250		2.0	0.10	0.10 - 0.50	8.10	17.3	17.5	21.2	27.4	27.1	30.5	32.3	35.0	31.8	41.2	49.4	37.5	19.1	37.8	29.2
	Fluoride (mg/L)	1.5		0.10	0.05	0.05 - 1.25	0.13	0.16	<0.05	0.13	<0.05	<0.05	<0.10	<0.10	0.12	0.23	<0.05	0.17	0.19	0.27	<0.10	0.21
	Nitrate as N (mg/L)	10.0		0.10	0.05	0.05 - 1.25	<0.10	0.11	<0.05	0.12	<0.05	<0.05	<0.10	<0.10	3.30	0.88	0.51	0.22	0.33	<0.05	<0.10	<0.10
	Nitrite as N (mg/L)	1.0		0.10	0.05	0.05 - 1.25	<0.10	<0.05	<0.05	<0.05	<0.05	<0.05	<0.10	<0.10	0.23	<0.05	<0.05	<0.05	<0.05	<0.05	<0.10	<0.10
	Phosphate-P (ortho) (mg/L)			0.30	0.10	0.10 - 2.50	<0.30	<0.10	<0.10	<0.10	<0.10	<0.10	<0.20	<0.20	<0.30	<0.10	<0.10	<0.10	<0.10	<0.10	<0.20	<0.20
	Sulphate (mg/L)	500		2.0	0.10	0.10 - 0.50	35.0	37.8	34.3	37.7	38.7	38.5	35.3	36.4	40.0	20.2	24.3	24.6	16.7	30	25.2	22.8
Metals	Aluminum (mg/L)	0.1	0.075	0.01	0.004	0.004	<0.01	0.02	<0.004	<0.004	0.009	0.008	0.005	<0.004	<0.01	2.04	<0.004	<0.004	0.007	0.005	0.004	0.008
	Antimony (mg/L)	0.006	0.02	0.005	0.006	0.003	<0.005	<0.006	<0.006	<0.006	<0.003	<0.003	<0.003	<0.003	<0.005	<0.006	<0.006	<0.006	<0.003	<0.003	<0.003	<0.003
	Arsenic (mg/L)	0.025	0.005	0.001	0.003	0.003	0.001	<0.003	<0.003	<0.003	<0.003	0.005	<0.003	<0.003	<0.001	0.004	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Barium (mg/L)	1.0		0.01	0.002	0.002	0.10	0.970	0.114	0.155	0.082	0.139	0.088	0.096	0.12	0.387	0.092	0.106	0.085	0.073	0.07	0.059
	Beryllium (mg/L)		1.1	0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Bismuth (mg/L)			0.001	0.002	0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Boron (mg/L)	5.0	0.2	0.05	0.010	0.010	<0.05	0.013	0.012	<0.010	<0.010	0.011	<0.010	0.014	<0.05	0.014	<0.010	<0.010	<0.010	<0.010	<0.010	0.01
	Cadmium (mg/L)	0.005	0.0005	0.0001	0.002	0.001	<0.0001	0.0006	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.0001	0.0025	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Calcium (mg/L)	200		0.5	0.05	0.05	79.0	79.9	79.4	82.8	80.7	83.5	91.5	82.6	90.0	70.8	78.4	82.4	75.5	71.5	77.8	62.4
	Chromium (mg/L)	0.05	0.0089	0.001	0.003	0.003	0.003	0.014	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.003	0.018	<0.003	<0.003	<0.003	<0.003	<0.003	0.003
	Cobalt (mg/L)		0.0009	0.0008	0.001	0.001	<0.0008	0.020	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0008	0.016	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Copper (mg/L)	1.0	0.005	0.001	0.003	0.002	0.001	0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.002	0.070	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Iron (mg/L)	0.3	0.3	0.05	0.010	0.010	<0.05	1.61	0.532	<0.010	1.65	0.195	1.3	1.17	0.06	2.47	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
	Lead (mg/L)	0.010	0.025	0.001	0.002	0.002	<0.001	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	0.591	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Magnesium (mg/L)			0.5	0.05	0.05	24	27.4	28.3	29.8	29.9	30	32.2	28.8	27	23.7	27.3	28.2	26.7	25.6	28.6	22.9
	Manganese (mg/L)	0.05		0.001	0.002	0.002	0.097	4.08	0.046	0.356	0.062	0.049	0.054	0.058	0.013	2.09	<0.002	0.006	<0.002	<0.002	<0.002	<0.002
	Molybdenum (mg/L)		0.04	0.001	0.002	0.001	0.004	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Nickel (mg/L)		0.025	0.002	0.003	0.003	0.002	0.037	<0.003	0.004	<0.003	<0.003	<0.003	<0.003	<0.002	0.023	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Phosphorus (mg/L)		0.01	0.05	0.05	0.05	<0.05	0.04	0.03	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	2.03	0.03	<0.05	<0.05	<0.05	<0.05	<0.05
	Potassium (mg/L)			0.5	0.05	0.05	1.5	2.27	0.83	1.38	0.73	1.06	0.84	0.87	1.2	1.28	0.77	1.06	0.88	0.82	0.86	0.8
	Selenium (mg/L)	0.01	0.1	0.005	0.004	0.004	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
	Silver (mg/L)		0.0001	0.0001	0.002	0.002	<0.0001	<0.0001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.0001	0.0002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Sodium (mg/L)	20		0.5	0.05	0.05	5.5	6.27	7.16	4.97	5.09	4.45	4.64	4.5	18	15.4	18.7	23.6	16.8	12.3	21.7	17.5
	Strontium (mg/L)			0.001	0.005	0.005	0.17	2.04	0.117	0.213	0.143	0.146	0.13	0.128	0.15	0.765	0.103	0.149	0.113	0.099	0.108	0.089
	Thallium (mg/L)		0.0003	0.0003	0.006	0.006	<0.0003	<0.0003	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.0003	<0.0003	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
	Tin (mg/L)			0.001	0.002	0.002	0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Titanium (mg/L)			0.002	0.002	0.002	<0.002	0.003	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.022	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Uranium (mg/L)	0.02	0.005	0.005	0.002	0.002	<0.005	0.006	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.005	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Vanadium (mg/L)		0.006	0.001	0.002	0.002	0.010	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.009	0.013	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Zinc (mg/L)	5	0.03	0.003	0.005	0.005	0.004	0.038	0.009	0.01	<0.005	0.006	<0.005	<0.005	0.012	0.328	0.016	0.018	0.007	0.009	0.01	0.01
Wet Chemistry	Alkalinity (CaCO3) (mg/L)	500		10	5	5	280	271	264	276	259	268	263	275	280	243	255	274	263	256	256	232
	Bicarbonate (CaCO3) (mg/L)			10	5	5	279	271	264	276	259	268	263	275	279	243	255	274	263	256	256	232
	Carbonate (CaCO3) (mg/L)			10	5	5	<10	<5	<5	<5	<5	<5	<5	<5	<10	<5	<5	<5	<5	<5	<5	<5
	Colour (TCU)	5		1	5	5	14	<5	<5	7	<5	<5	<5	<5	11	5	<5	5	<5	<5	<5	<5
	Total Organic Carbon (mg/L)				0.5	0.5	na	34.2	7.9	3.5	1.9	21.9	2.9	50.4	na	15.7	2.5	4.3	1.4	13	3.2	39.2
	DOC (mg/L)	5		0.7	0.5	0.5	2.5	1.6	6.9	1.6	1.7	9.6	2.5	21.7	1.7	3.0	2.2	1.9	1.4	3.2	1.6	15.6
	Hardness (CaCO3) (mg/L)	100		10	10	10	296	312	315	329	325	332	361	325	336	274	308	322	298	284	312	250
	Ammonia as N (mg/L)			0.05	0.02	0.02	<0.05	<0.02	<0.02	0.09	0.06	0.07	0.05	0.18	<0.05	<0.02	<0.02	0.03	<0.02	<0.02	<0.02	0.05
	Conductivity (us/cm)			3	2	2	570	563	602	577	596	597	646	642	730	551	645	645	592	544	643	565
	pH	8.5	6.5 - 8.5	0.1	N/A	N/A	7.6	7.83	8.06	8.06	7.89	8.21	8.12	7.88	7.5	7.78	8.08	7.96	7.71	8.13	7.98	7.9
Calculated Values	Anion sum (meq/L)			0.01			6.57	5.82		6.01	6.76	6.93	6.86	7.17	7.66	5.46		6.51	6.7	6.3	6.71	5.95
	Cation sum (meq/L)			0.01			6.20	6.57		6.84	6.73	6.86	7.44	6.72	7.53	6.18		7.49	6.72	6.23	7.2	5.78
	% Difference (%)			0.01	0.1	0.1	-5.79	6.1	1	0.6	0.2	0.5	4.1	3.2	-1.71	6.3	1.3	0.5	0.1	0.5	3.5	1.4
	Langelier Index			0.0001			-0.07	0.9	1.12	1.16	0.95	1.3	1.24	0.97	-0.04	0.74	1.12	1.05	0.74	1.13	1.02	0.83
	Saturation pH (pH units)			0.01			7.68	6.93	6.94	6.9	6.94	6.91	6.88	6.91	7.65	7.04	6.96	6.91	6.97	7	6.96	7.07
	Silica (mg/L)				0.05	0.05	14.2	15.9	7.48	15.7	16.1	6.87	19.1	16.5	12.5	9.9	3.94	10.6	7.91	3.77	10.6	9.2

At or Exceeds ODWQS

Hanlon Creek Business Park - Groundwater Monitoring Program

Groundwater Quality

	Parameter (units)	ODWQS	PWQO	RDL			Monitoring Wells 118								118A							
				2003	2008-10	2011-14	2003	2008	2009	2010	2011	2012	2013	2014	2003	2008	2009	2010	2011	2012	2013	2014
Anions	Chloride (mg/L)	250		2.0	0.10	0.10 - 0.50	6.40	0.44	12	0.73	0.82	0.98	0.99	1.06	220	137	217	195	185	285	292	336
	Fluoride (mg/L)	1.5		0.10	0.05	0.05 - 1.25	0.50	0.59	0.53	0.46	0.54	0.58	0.46	0.52	0.11	0.06	<0.05	<0.05	<0.05	<0.05	<0.5	<0.5
	Nitrate as N (mg/L)	10.0		0.10	0.05	0.05 - 1.25	<0.10	0.11	0.28	<0.05	<0.05	<0.05	<0.05	<0.10	11.0	4.02	3.82	3.41	3.03	2.18	1.84	1.48
	Nitrite as N (mg/L)	1.0		0.10	0.05	0.05 - 1.25	<0.10	0.08	<0.05	<0.05	<0.05	<0.05	<0.05	<0.10	<0.30	<0.05	<0.05	<0.05	<0.05	<0.05	<0.5	<0.5
	Phosphate-P (ortho) (mg/L)			0.30	0.10	0.10 - 2.50	<0.30	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.20	<0.30	<0.10	<0.10	<0.10	<0.10	<0.10	<1.0	<1.0
	Sulphate (mg/L)	500		2.0	0.10	0.10 - 0.50	20.0	12.7	11.2	10.4	10.6	10.3	10.3	10.3	23.0	25.8	20.7	18.2	20.7	26.7	39.1	31.4
Metals	Aluminum (mg/L)	0.1	0.075	0.01	0.004	0.004	<0.01	0.035	0.344	<0.004	0.009	0.007	0.006	<0.004	<0.01	1.20	<0.004	<0.004	0.008	0.004	0.008	<0.004
	Antimony (mg/L)	0.006	0.02	0.005	0.006	0.003	<0.005	<0.006	<0.006	<0.006	<0.003	<0.003	<0.003	<0.003	<0.005	<0.006	<0.006	<0.006	<0.003	<0.003	<0.003	<0.003
	Arsenic (mg/L)	0.025	0.005	0.001	0.003	0.003	0.003	0.004	0.006	0.009	0.009	0.01	0.008	0.009	<0.001	0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Barium (mg/L)	1.0		0.01	0.002	0.002	0.15	1.190	0.137	0.142	0.099	0.124	0.115	0.09	0.10	0.938	0.093	0.113	0.09	0.1	0.087	0.094
	Beryllium (mg/L)		1.1	0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Bismuth (mg/L)			0.001	0.002	0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Boron (mg/L)	5.0	0.2	0.05	0.010	0.010	<0.05	0.018	0.023	0.025	0.027	0.025	0.024	0.026	<0.05	0.013	0.01	0.011	<0.010	0.011	<0.010	0.014
	Cadmium (mg/L)	0.005	0.0005	0.0001	0.002	0.001	<0.0001	0.0012	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.0001	0.0154	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Calcium (mg/L)	200		0.5	0.05	0.05	46.0	38.3	47.3	41.5	40	39	40.8	38.2	100	89.7	102	107	98.1	101	92.5	95.6
	Chromium (mg/L)	0.05	0.0089	0.001	0.003	0.003	0.003	0.013	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.004	0.014	0.003	<0.003	<0.003	0.01	<0.003	<0.003
	Cobalt (mg/L)		0.0009	0.0008	0.001	0.001	<0.0008	0.017	0.004	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0008	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Copper (mg/L)	1.0	0.005	0.001	0.003	0.002	<0.001	<0.003	0.006	<0.003	<0.003	<0.003	<0.003	<0.003	0.002	0.115	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Iron (mg/L)	0.3	0.3	0.05	0.010	0.010	<0.05	5.6	1.06	0.032	0.283	0.098	0.037	0.182	0.09	2.35	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
	Lead (mg/L)	0.010	0.025	0.001	0.002	0.002	<0.001	0.001	0.027	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	0.032	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Magnesium (mg/L)			0.5	0.05	0.05	25	25.6	26.2	28.4	27.6	27.2	27.6	25.5	29	27.2	31	32.6	30.8	31	28.2	29.4
	Manganese (mg/L)	0.05		0.001	0.002	0.002	0.003	4.87	0.191	0.008	0.008	0.016	0.012	0.008	0.003	3.3	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Molybdenum (mg/L)		0.04	0.001	0.002	0.001	0.009	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Nickel (mg/L)		0.025	0.002	0.003	0.003	<0.002	0.038	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.002	0.066	<0.003	0.004	<0.003	<0.003	<0.003	<0.003
	Phosphorus (mg/L)		0.01	0.05	0.05	0.05	<0.05	0.03	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	1.03	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Potassium (mg/L)			0.5	0.05	0.05	2.0	1.67	1.04	1.1	0.91	1.08	0.94	0.95	2.3	2.52	1.67	1.59	1.44	1.82	1.45	1.95
	Selenium (mg/L)	0.01	0.1	0.005	0.004	0.004	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
	Silver (mg/L)		0.0001	0.0001	0.002	0.002	<0.0001	<0.0001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.0001	0.0003	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Sodium (mg/L)	20		0.5	0.05	0.05	11	6.41	11.9	6.41	6.41	6.41	6.46	6.77	110	80.7	105	99.7	91.1	160	152	206
	Strontium (mg/L)			0.001	0.005	0.005	0.28	1.97	0.265	0.285	0.284	0.245	0.258	0.226	0.14	0.94	0.11	0.14	0.124	0.113	0.116	0.118
	Thallium (mg/L)		0.0003	0.0003	0.006	0.006	<0.0003	<0.0003	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.0003	<0.0003	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
	Tin (mg/L)			0.001	0.002	0.002	0.001	<0.002	<0.002	<0.002	<0.002	<0.002	0.002	<0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Titanium (mg/L)			0.002	0.002	0.002	<0.002	0.003	0.026	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.004	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Uranium (mg/L)	0.02	0.005	0.005	0.002	0.002	<0.005	0.01	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.005	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Vanadium (mg/L)		0.006	0.001	0.002	0.002	0.010	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.009	0.004	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Zinc (mg/L)	5	0.03	0.003	0.005	0.005	0.018	0.067	0.114	<0.005	0.006	<0.005	<0.005	<0.005	0.011	2.14	0.086	0.026	0.01	0.012	0.019	0.012
Wet Chemistry	Alkalinity (CaCO3) (mg/L)	500		10	5	5	230	237	208	213	216	214	213	207	270	296	282	316	305	313	316	329
	Bicarbonate (CaCO3) (mg/L)			10	5	5	228	237	203	209	216	214	211	207	269	296	282	316	305	313	316	329
	Carbonate (CaCO3) (mg/L)			10	5	5	<10	<5	5	5	<5	<5	<5	<5	<10	<5	<5	<5	<5	<5	<5	<5
	Colour (TCU)	5		1	5	5	14	<5	<5	<5	<5	<5	<5	<5	<1	<5	<5	10	<5	<5	<5	<5
	Total Organic Carbon (mg/L)				0.5	0.5	na	6.1	1.8	1.7	1.9	4.1	3	13.8	na	27.5	5.9	1.3	1	18.3	2	24.7
	DOC (mg/L)	5		0.7	0.5	0.5	1.8	0.8	1.2	1.3	1.5	2.3	3	9.4	0.8	4.8	6.0	1.6	0.9	2.7	2	11.3
	Hardness (CaCO3) (mg/L)	100		10	10	10	218	201	226	221	214	209	216	200	369	336	382	401	372	380	347	360
	Ammonia as N (mg/L)			0.05	0.02	0.02	0.13	0.26	0.16	<0.02	0.21	0.1	0.33	0.33	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	0.03	0.03
	Conductivity (us/cm)			3	2	2	400	388	439	379	383	387	414	412	1300	935	1220	1130	1070	1430	1560	1690
	pH	8.5	6.5 - 8.5	0.1	N/A	N/A	7.9	8.2	8.35	8.31	8.01	8.09	8.31	8.02	7.5	7.92	8.04	8.05	7.73	8	8.16	8.1
Calculated Values	Anion sum (meq/L)			0.01			5.23	4.28	4.75	3.92	4.59	4.55	4.53	4.41	12.9	9.64	12.5	11.4	12	15	15.5	16.8
	Cation sum (meq/L)			0.01			4.89	4.35	5.07	4.71	4.58	4.49	4.63	4.34	12.2	10.3	12.2	12.4	11.4	14.6	13.6	16.2
	% Difference (%)			0.01	0.1	0.1	-6.72	0.8	3.2	2	0.1	0.7	1.1	0.8	-5.18	3.2	0.9	0.2	2.3	1.4	6.6	1.9
	Langelier Index			0.0001			-0.06	1.05	1.19	1.15	0.84	0.91	1.14	0.81	-0.18	1.03	1.18	1.26	0.89	1.19	1.31	1.27
	Saturation pH (pH units)			0.01			7.97	7.15	7.16	7.16	7.17	7.18	7.17	7.21	7.69	6.89	6.86	6.79	6.84	6.81	6.85	6.83
	Silica (mg/L)				0.05	0.05	15.8	19.4	8.8	18.7	20.6	8.54	23.1	21.8	10.9	8.08	3.78	9.59	8.84	3.45	9.33	7.99

At or Exceeds ODWQS

Hanlon Creek Business Park - Groundwater Monitoring Program

Groundwater Quality

	Parameter (units)	ODWQS	PWQO	RDL			Monitoring Wells 119								119A								120	120A
				2003	2008-10	2011-14	2003	2008	2009	2010	2011	2012	2013	2014	2003	2008	2009	2010	2011	2012	2013	2014	2003	2003
Anions	Chloride (mg/L)	250		2.0	0.10	0.10 - 0.50	32.0	28.7	28.9	29.4	29.8	29.4	82	132	30.0	19.3	23.1	27.2	74.4	127	108	165	17.0	34.0
	Fluoride (mg/L)	1.5		0.10	0.05	0.05 - 1.25	<0.10	0.05	<0.05	<0.05	<0.05	<0.05	<0.25	<0.10	<0.10	0.06	<0.05	<0.05	<0.05	<0.05	<0.25	<0.10	<0.10	<0.10
	Nitrate as N (mg/L)	10.0		0.10	0.05	0.05 - 1.25	0.25	<0.05	<0.05	<0.05	<0.05	<0.05	<0.25	<0.10	<0.10	<0.05	<0.05	<0.05	1.95	0.19	<0.25	<0.10	0.22	4.40
	Nitrite as N (mg/L)	1.0		0.10	0.05	0.05 - 1.25	0.19	<0.05	<0.05	<0.05	<0.05	<0.05	<0.25	<0.10	<0.10	<0.05	<0.05	<0.05	<0.05	<0.05	<0.25	<0.10	0.13	<0.10
	Phosphate-P (ortho) (mg/L)			0.30	0.10	0.10 - 2.50	<0.30	<0.10	<0.10	<0.10	<0.10	<0.10	<0.50	<0.20	<0.30	<0.10	<0.10	<0.10	<0.10	<0.10	<0.50	<0.20	<0.30	<0.30
	Sulphate (mg/L)	500		2.0	0.10	0.10 - 0.50	96.0	67.7	61.8	61.7	61.9	53.1	37.9	28.4	81.0	25.5	15.7	7.83	26.6	43.4	23.8	22.9	67.0	51.0
Metals	Aluminum (mg/L)	0.1	0.075	0.01	0.004	0.004	<0.01	1.06	0.01	0.006	0.016	0.017	0.01	<0.004	<0.01	1.74	0.004	0.004	0.014	0.025	0.013	<0.004	<0.01	<0.01
	Antimony (mg/L)	0.006	0.02	0.005	0.006	0.003	<0.005	<0.006	<0.006	<0.006	<0.003	<0.003	<0.003	<0.003	<0.005	<0.006	<0.006	<0.006	<0.003	<0.003	<0.003	<0.003	<0.005	<0.005
	Arsenic (mg/L)	0.025	0.005	0.001	0.003	0.003	0.002	0.01	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.002	0.008	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.001	<0.001
	Barium (mg/L)	1.0		0.01	0.002	0.002	0.07	0.169	0.048	0.046	0.041	0.043	0.04	0.04	0.09	0.339	0.06	0.076	0.065	0.071	0.051	0.086	0.16	0.08
	Beryllium (mg/L)		1.1	0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Bismuth (mg/L)			0.001	0.002	0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	<0.001
	Boron (mg/L)	5.0	0.2	0.05	0.010	0.010	0.11	0.018	0.011	0.01	0.01	<0.010	<0.010	0.01	<0.05	0.013	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.23	<0.05
	Cadmium (mg/L)	0.005	0.0005	0.0001	0.002	0.001	<0.0001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.0001	0.006	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.0001	<0.0001
	Calcium (mg/L)	200		0.5	0.05	0.05	110	94.4	98.2	103	96.6	100	102	85.6	110	89.0	94.1	97.9	70.5	86.6	69	79.6	72.0	89.0
	Chromium (mg/L)	0.05	0.0089	0.001	0.003	0.003	0.003	0.004	<0.003	<0.003	<0.003	0.004	<0.003	0.004	0.005	0.004	<0.003	<0.003	<0.003	0.007	<0.003	0.004	0.003	0.003
	Cobalt (mg/L)		0.0009	0.0008	0.001	0.001	0.0009	0.008	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0008	0.010	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0008	<0.0008
	Copper (mg/L)	1.0	0.005	0.001	0.003	0.002	0.002	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.002	0.007	<0.003	<0.003	0.003	<0.003	0.004	<0.003	<0.001	0.001
	Iron (mg/L)	0.3	0.3	0.05	0.010	0.010	0.08	10.1	1.02	1.22	1.22	1.14	1.07	0.722	0.08	8.68	0.259	0.875	0.024	<0.010	<0.010	0.029	<0.05	0.06
	Lead (mg/L)	0.010	0.025	0.001	0.002	0.002	<0.001	0.02	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	0.044	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	<0.001
	Magnesium (mg/L)			0.5	0.05	0.05	31	29.3	30.7	32.5	30.6	31.6	30.6	26.2	35	26.6	28.6	30	22.8	27.7	21.5	25.6	22	24
	Manganese (mg/L)	0.05		0.001	0.002	0.002	0.16	3.75	0.124	0.154	0.108	0.11	0.12	0.094	0.20	5.2	0.573	0.536	0.057	0.34	0.369	0.701	0.063	0.004
	Molybdenum (mg/L)		0.04	0.001	0.002	0.001	0.010	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.009	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.013	<0.001
	Nickel (mg/L)		0.025	0.002	0.003	0.003	0.005	<0.003	<0.003	0.004	<0.003	<0.003	<0.003	<0.003	<0.002	<0.003	0.005	0.007	<0.003	<0.003	<0.003	<0.003	<0.002	<0.002
	Phosphorus (mg/L)		0.01	0.05	0.05	0.05	<0.05	1.74	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.21	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Potassium (mg/L)			0.5	0.05	0.05	1.9	1.64	0.99	0.99	1.08	1.06	1.02	1.41	2.5	1.6	1.05	1.01	1.21	1.4	1.33	1.73	2.8	3.3
	Selenium (mg/L)	0.01	0.1	0.005	0.004	0.004	<0.005	0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.005
	Silver (mg/L)		0.0001	0.0001	0.002	0.002	<0.0001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.0001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.0001	<0.0001
	Sodium (mg/L)	20		0.5	0.05	0.05	21	8.52	7.79	8.89	9.15	10.7	18.7	52.5	12	6.23	7.56	9.19	31	52.4	51.3	83.3	16	12
	Strontium (mg/L)			0.001	0.005	0.005	0.73	2	0.12	0.145	0.141	0.143	0.133	0.118	0.21	2.17	0.087	0.104	0.077	0.094	0.078	0.104	0.13	0.11
	Thallium (mg/L)		0.0003	0.0003	0.006	0.006	<0.0003	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.0003	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.0003	<0.0003
	Tin (mg/L)			0.001	0.002	0.002	0.008	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.002	<0.001
	Titanium (mg/L)			0.002	0.002	0.002	<0.002	0.029	<0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.005	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Uranium (mg/L)	0.02	0.005	0.005	0.002	0.002	<0.005	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.006	0.002	<0.002	<0.002	0.003	<0.002	<0.002	0.002	<0.005	<0.005
	Vanadium (mg/L)		0.006	0.001	0.002	0.002	0.010	0.007	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.013	0.007	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.009	0.008
	Zinc (mg/L)	5	0.03	0.003	0.005	0.005	0.011	0.217	0.013	0.006	0.01	0.011	0.007	<0.005	0.014	0.519	0.035	0.03	0.015	0.042	0.023	0.017	0.005	0.007
Wet Chemistry	Alkalinity (CaCO3) (mg/L)	500		10	5	5	300	296	298	303	289	312	274	226	350	312	303	330	210	240	212	236	240	250
	Bicarbonate (CaCO3) (mg/L)			10	5	5	299	278	298	303	289	312	274	226	349	294	303	330	210	235	212	236	239	249
	Carbonate (CaCO3) (mg/L)			10	5	5	<10	18	<5	<5	<5	<5	<5	<5	<10	18	<5	<5	<5	6	<5	<5	<10	<10
	Colour (TCU)	5		1	5	5	19	8	13	14	15	25	<5	6	28	10	10	11	5	6	<5	5	35	26
	Total Organic Carbon (mg/L)				0.5	0.5	na	4.9	9.8	6.1	7	7.5	4	4.3	na	5.1	5.5	6.4	4.4	6.1	6	5.3	na	na
	DOC (mg/L)	5		0.7	0.5	0.5	3.1	4.9	9.6	5.8	6.4	6	4	3.6	7.3	5.1	5.4	5.8	3.8	2.8	5	4.5	1.3	1.1
	Hardness (CaCO3) (mg/L)	100		10	10	10	402	356	372	391	367	380	381	322	419	332	353	368	270	330	261	304	270	321
	Ammonia as N (mg/L)			0.05	0.02	0.02	<0.05	0.21	<0.02	0.03	0.05	0.04	0.17	0.12	<0.05	<0.02	<0.02	<0.02	0.03	<0.02	0.05	0.05	<0.05	<0.05
	Conductivity (us/cm)			3	2	2	800	676	722	679	671	695	839	899	850	611	646	634	632	853	796	1020	540	700
	pH	8.5	6.5 - 8.5	0.1	N/A	N/A	7.4	8.36	7.95	8.02	7.61	8.18	8.05	8.04	7.4	8.35	8.05	8.23	8.04	8.32	8.14	8.08	7.7	7.5
Calculated Values	Anion sum (meq/L)			0.01			8.92	8.14	8.06	7.18	7.91	8.17	8.58	8.83	9.54	7.32	7.04	6.45	6.99	9.3	7.78	9.85	6.69	7.34
	Cation sum (meq/L)			0.01			9.01	7.55	7.79	8.23	7.77	8.09	8.46	8.75	8.96	6.94	7.4	7.78	6.77	8.91	7.48	9.75	6.17	7.03
	% Difference (%)			0.01	0.1	0.1	1.00	3.8	1.7	0.3	0.9	0.5	0.7	0.5	-6.27	2.6	2.5	1.6	1.6	2.1	2	0.5	-8.09	-4.31
	Langelier Index			0.0001			-0.17	1.52	1.13	1.23	0.78	1.39	1.21	1.04	-0.10	1.5	1.22	1.45	0.93	1.36	1.02	1.05	-0.09	-0.19
	Saturation pH (pH units)			0.01			7.57	6.84	6.82	6.79	6.83	6.79	6.84	7	7.50	6.85	6.83	6.78	7.11	6.96	7.12	7.03	7.80	7.70
	Silica (mg/L)				0.05	0.05	11.1	10.3	3.94	9.45	8.42	4.11	9.76	8.69	11.9	6.42	2.47	6.45	4.31	2.18	4.52	4.48	11.2	10.0

At or Exceeds ODWQS

Hanlon Creek Business Park - Groundwater Monitoring Program

Groundwater Quality

	Parameter (units)	ODWQS	PWQO	RDL			Monitoring Wells 121								121A							
				2003	2008-10	2011-14	2003	2008	2009	2010	2011	2012	2013	2014	2003	2008	2009	2010	2011	2012	2013	2014
Anions	Chloride (mg/L)	250		2.0	0.10	0.10 - 0.50	52.0	45.2	105	54.3	61.2	68.9	60.9	68.3	38.0	62.7	48.5	81.1	96.1	89.8	42.8	53.4
	Fluoride (mg/L)	1.5		0.10	0.05	0.05 - 1.25	<0.10	0.08	<0.05	<0.05	<0.05	<0.05	<0.25	<1.25	<0.10	0.06	<0.05	0.05	<0.05	<0.05	<0.25	<1.25
	Nitrate as N (mg/L)	10.0		0.10	0.05	0.05 - 1.25	2.40	3.00	4.45	3.63	3.66	3.34	3.26	3.54	10.0	4.62	2.85	2.44	1.91	2.53	1.10	1.71
	Nitrite as N (mg/L)	1.0		0.10	0.05	0.05 - 1.25	0.26	<0.05	<0.05	<0.05	<0.05	<0.05	<0.25	<1.25	<0.10	<0.05	<0.05	<0.05	<0.05	<0.05	<0.25	<1.25
	Phosphate-P (ortho) (mg/L)			0.30	0.10	0.10 - 2.50	<0.30	<0.10	<0.10	<0.10	<0.10	<0.10	<0.50	<2.50	<0.30	<0.10	<0.10	<0.10	<0.10	<0.10	<0.50	<2.50
	Sulphate (mg/L)	500		2.0	0.10	0.10 - 0.50	55.0	41.5	15.8	35.4	36.7	28.2	28.3	32	27.0	16.3	41.6	15	17.5	12.9	8.89	10.4
Metals	Aluminum (mg/L)	0.1	0.075	0.01	0.004	0.004	<0.01	0.533	<0.004	<0.004	0.007	0.008	0.006	<0.004	<0.01	4.19	1.48	<0.004	0.007	0.011	0.02	<0.004
	Antimony (mg/L)	0.006	0.02	0.005	0.006	0.003	<0.005	<0.006	<0.006	<0.006	<0.003	<0.003	<0.003	<0.003	<0.005	<0.006	<0.006	<0.006	<0.003	<0.003	<0.003	<0.003
	Arsenic (mg/L)	0.025	0.005	0.001	0.003	0.003	<0.001	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.001	<0.003	0.005	<0.003	<0.003	<0.003	<0.003	<0.003
	Barium (mg/L)	1.0		0.01	0.002	0.002	0.10	0.325	0.064	0.119	0.116	0.086	0.068	0.095	0.09	0.310	0.163	0.078	0.079	0.061	0.038	0.043
	Beryllium (mg/L)		1.1	0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Bismuth (mg/L)			0.001	0.002	0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Boron (mg/L)	5.0	0.2	0.05	0.010	0.010	0.17	0.012	0.011	<0.010	<0.010	<0.010	<0.010	<0.010	<0.05	<0.010	<0.010	0.013	0.013	0.011	<0.010	0.01
	Cadmium (mg/L)	0.005	0.0005	0.0001	0.002	0.001	<0.0001	0.0043	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.0001	0.0071	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002
	Calcium (mg/L)	200		0.5	0.05	0.05	77.0	84.9	92.9	90.6	86.8	80.6	80.5	88.3	95.0	83.3	89.3	97.2	91.3	79.7	71	77.9
	Chromium (mg/L)	0.05	0.0089	0.001	0.003	0.003	0.003	0.010	0.004	<0.003	<0.003	0.006	<0.003	<0.003	0.003	0.023	0.011	<0.003	<0.003	0.007	<0.003	<0.003
	Cobalt (mg/L)		0.0009	0.0008	0.001	0.001	0.0011	0.010	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0008	0.042	0.003	<0.001	<0.001	<0.001	<0.001	<0.001
	Copper (mg/L)	1.0	0.005	0.001	0.003	0.002	0.002	0.016	<0.003	<0.003	<0.003	<0.002	<0.003	<0.003	0.001	0.134	0.017	<0.003	<0.003	<0.002	<0.003	<0.003
	Iron (mg/L)	0.3	0.3	0.05	0.010	0.010	<0.05	5.16	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.07	11.8	5.44	<0.010	<0.010	<0.010	<0.010	<0.010
	Lead (mg/L)	0.010	0.025	0.001	0.002	0.002	<0.001	0.017	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	0.528	0.079	<0.002	<0.002	<0.002	<0.002	<0.002
	Magnesium (mg/L)			0.5	0.05	0.05	26	28.9	27.4	31.6	31	26.7	26.5	30.8	25	23.8	31.8	30	30.9	24.5	20.8	22.7
	Manganese (mg/L)	0.05		0.001	0.002	0.002	0.29	2.61	<0.002	0.002	<0.002	<0.002	<0.002	<0.002	0.020	3.14	0.721	<0.002	<0.002	<0.002	<0.002	<0.002
	Molybdenum (mg/L)		0.04	0.001	0.002	0.001	0.014	<0.002	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002
	Nickel (mg/L)		0.025	0.002	0.003	0.003	0.003	0.010	<0.003	0.004	<0.003	<0.003	<0.003	<0.003	<0.002	0.036	0.003	0.004	<0.003	<0.003	<0.003	<0.003
	Phosphorus (mg/L)		0.01	0.05	0.05	0.05	<0.05	2.78	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	1.02	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Potassium (mg/L)			0.5	0.05	0.05	2.2	2.03	1.52	1.34	1.51	1.37	1.25	1.3	4.3	3.89	1.36	2.45	3.71	1.02	1.19	0.96
	Selenium (mg/L)	0.01	0.1	0.005	0.004	0.004	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
	Silver (mg/L)		0.0001	0.0001	0.002	0.002	<0.0001	<0.0001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.0001	0.0001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Sodium (mg/L)	20		0.5	0.05	0.05	24	13.4	38.8	15.4	17.4	24.9	19.6	22.0	18	30.2	12.1	38.4	41.2	39.5	22.8	30.1
	Strontium (mg/L)			0.001	0.005	0.005	0.22	1.04	0.108	0.12	0.104	0.091	0.114	0.104	0.13	0.469	0.318	0.119	0.111	0.105	0.101	0.08
	Thallium (mg/L)		0.0003	0.0003	0.006	0.006	<0.0003	<0.0003	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.0003	<0.0003	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
	Tin (mg/L)			0.001	0.002	0.002	0.008	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Titanium (mg/L)			0.002	0.002	0.002	<0.002	0.004	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.062	0.045	<0.002	<0.002	<0.002	<0.002	<0.002
	Uranium (mg/L)	0.02	0.005	0.005	0.002	0.002	<0.005	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.005	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Vanadium (mg/L)		0.006	0.001	0.002	0.002	0.008	0.003	<0.002	<0.002	<0.002	<0.002	0.002	<0.002	0.009	0.012	0.007	<0.002	<0.002	<0.002	<0.002	<0.002
	Zinc (mg/L)	5	0.03	0.003	0.005	0.005	0.010	0.434	0.017	0.031	0.025	0.031	0.034	0.03	0.028	1.79	0.272	0.017	0.012	0.023	0.018	0.008
Wet Chemistry	Alkalinity (CaCO3) (mg/L)	500		10	5	5	250	259	273	261	251	267	261	259	280	266	244	305	293	284	274	265
	Bicarbonate (CaCO3) (mg/L)			10	5	5	249	259	273	261	251	267	261	259	279	266	244	305	293	284	274	265
	Carbonate (CaCO3) (mg/L)			10	5	5	<10	<5	<5	<5	<5	<5	<5	<5	<10	<5	<5	<5	<5	<5	<5	<5
	Colour (TCU)	5		1	5	5	22	<5	<5	<5	<5	<5	<5	<5	23	<5	<5	5	<5	<5	<5	<5
	Total Organic Carbon (mg/L)				0.5	0.5	na	9.4	5.6	1.2	<0.5	2	1	1.2	na	9.4	2.5	1.6	0.8	1.4	2	1.5
	DOC (mg/L)	5		0.7	0.5	0.5	2.1	1.2	1.9	1.3	<0.5	1	1.1	1.1	1.1	1.9	0.7	1.5	0.8	0.9	2	1.4
	Hardness (CaCO3) (mg/L)	100		10	10	10	299	331	345	356	344	311	310	347	340	306	354	366	355	300	263	288
	Ammonia as N (mg/L)			0.05	0.02	0.02	<0.05	0.15	<0.02	0.02	<0.02	<0.02	<0.02	0.03	<0.05	0.25	<0.02	<0.02	<0.02	<0.02	<0.02	0.04
	Conductivity (us/cm)			3	2	2	720	643	845	671	699	736	745	790	770	694	684	794	811	789	652	703
	pH	8.5	6.5 - 8.5	0.1	N/A	N/A	7.6	7.76	7.87	8.16	8.04	8.04	8.13	8.19	7.5	7.73	7.88	8.07	7.92	8.04	8.11	8.09
Calculated Values	Anion sum (meq/L)			0.01			7.78	6.69		6.89	7.77	8.11	7.76	8.03	7.95	6.89		7.88	9.07	8.66	6.95	7.14
	Cation sum (meq/L)			0.01			7.09	7.26		7.83	7.68	7.34	7.08	7.93	7.69	7.55		9.05	8.98	7.74	6.28	7.09
	% Difference (%)			0.01	0.1	0.1	-9.28	4.1	2.6	0.5	0.6	5	4.6	0.6	-3.32	4.6	2.1	1	0.5	5.6	5.1	0.4
	Langelier Index			0.0001			-0.17	0.83	1.14	1.27	1.12	1.1	1.18	1.28	-0.12	0.78	1.12	1.26	1.08	1.11	1.11	1.11
	Saturation pH (pH units)			0.01			7.77	6.93	6.73	6.89	6.92	6.94	6.95	6.91	7.62	6.95	6.76	6.81	6.84	6.93	7	6.98
	Silica (mg/L)				0.05	0.05	10.1	13.4	3.77	12.8	13	11.5	13.4	12.2	11.0	8.03	5.73	9.03	8.22	8.98	8.27	7.6

At or Exceeds ODWQS

Hanlon Creek Business Park - Groundwater Monitoring Program

Groundwater Quality

	Parameter (units)	ODWQS	PWQO	RDL 2003	RDL 2008-10	RDL 2011-14	122 2003	122 2008	122 2009	122 2010	122 2011	122 2012	122 2013	122 2014
Anions	Chloride (mg/L)	250		2.0	0.10	0.10 - 0.50	44.0	63.6	66.1	62.6	66.7	64.4	66.7	67.6
	Fluoride (mg/L)	1.5		0.10	0.05	0.05 - 1.25	<0.10	0.05	<0.05	0.05	<0.05	<0.05	<0.25	<0.10
	Nitrate as N (mg/L)	10.0		0.10	0.05	0.05 - 1.25	7.80	11.6	8.71	7.08	6.45	5.41	5.64	4.55
	Nitrite as N (mg/L)	1.0		0.10	0.05	0.05 - 1.25	0.26	<0.05	<0.05	<0.05	<0.05	<0.05	<0.25	<0.10
	Phosphate-P (ortho) (mg/L)			0.30	0.10	0.10 - 2.50	<0.30	<0.10	<0.10	<0.10	<0.10	<0.10	<0.50	<0.20
	Sulphate (mg/L)	500		2.0	0.10	0.10 - 0.50	63.0	22.1	22.7	22.2	22.1	19.8	19.1	18.2
Metals	Aluminum (mg/L)	0.1	0.075	0.01	0.004	0.004	<0.01	0.831	0.004	<0.004	0.008	0.007	<0.004	<0.004
	Antimony (mg/L)	0.006	0.02	0.005	0.006	0.003	<0.005	<0.006	<0.006	<0.006	<0.003	<0.003	<0.003	<0.003
	Arsenic (mg/L)	0.025	0.005	0.001	0.003	0.003	<0.001	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Barium (mg/L)	1.0		0.01	0.002	0.002	0.09	0.156	0.093	0.099	0.095	0.081	0.089	0.076
	Beryllium (mg/L)		1.1	0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Bismuth (mg/L)			0.001	0.002	0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Boron (mg/L)	5.0	0.2	0.05	0.010	0.010	0.05	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
	Cadmium (mg/L)	0.005	0.0005	0.0001	0.002	0.001	<0.0001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Calcium (mg/L)	200		0.5	0.05	0.05	89.0	85.4	101	95.4	86.7	88.7	81.1	86
	Chromium (mg/L)	0.05	0.0089	0.001	0.003	0.003	0.003	0.006	0.003	<0.003	<0.003	<0.003	<0.003	0.004
	Cobalt (mg/L)		0.0009	0.0008	0.001	0.001	<0.0008	0.005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Copper (mg/L)	1.0	0.005	0.001	0.003	0.002	0.001	0.015	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Iron (mg/L)	0.3	0.3	0.05	0.010	0.010	0.06	2.54	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
	Lead (mg/L)	0.010	0.025	0.001	0.002	0.002	<0.001	0.06	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Magnesium (mg/L)			0.5	0.05	0.05	28	26.8	30.6	29.3	26.9	28.1	24.8	25.5
	Manganese (mg/L)	0.05		0.001	0.002	0.002	0.14	0.864	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Molybdenum (mg/L)		0.04	0.001	0.002	0.001	0.006	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Nickel (mg/L)		0.025	0.002	0.003	0.003	<0.002	<0.003	<0.003	0.004	<0.003	<0.003	<0.003	<0.003
	Phosphorus (mg/L)		0.01	0.05	0.05	0.05	<0.05	0.86	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Potassium (mg/L)			0.5	0.05	0.05	1.5	1.79	1.29	1.42	1.34	1.39	1.14	1.33
	Selenium (mg/L)	0.01	0.1	0.005	0.004	0.004	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
	Silver (mg/L)		0.0001	0.0001	0.002	0.002	<0.0001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Sodium (mg/L)	20		0.5	0.05	0.05	27	19.4	20.6	22.5	21.2	24.3	22.1	25.8
	Strontium (mg/L)			0.001	0.005	0.005	0.20	0.407	0.111	0.119	0.109	0.099	0.11	0.096
	Thallium (mg/L)		0.0003	0.0003	0.006	0.006	<0.0003	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
	Tin (mg/L)			0.001	0.002	0.002	0.003	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Titanium (mg/L)			0.002	0.002	0.002	<0.002	0.015	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Uranium (mg/L)	0.02	0.005	0.005	0.002	0.002	<0.005	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Vanadium (mg/L)		0.006	0.001	0.002	0.002	0.009	0.005	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Zinc (mg/L)	5	0.03	0.003	0.005	0.005	0.019	0.229	0.037	0.02	0.016	0.019	0.015	0.016
Wet Chemistry	Alkalinity (CaCO3) (mg/L)	500		10	5	5	270	267	255	274	258	259	262	268
	Bicarbonate (CaCO3) (mg/L)			10	5	5	269	267	255	274	258	259	262	268
	Carbonate (CaCO3) (mg/L)			10	5	5	<10	<5	<5	<5	<5	<5	<5	<5
	Colour (TCU)	5		1	5	5	27	<5	<5	5	<5	<5	<5	<5
	Total Organic Carbon (mg/L)				0.5	0.5	na	3.5	5.6	1.2	0.9	1.1	1.2	3.6
	DOC (mg/L)	5		0.7	0.5	0.5	2.1	0.9	4.9	1.2	0.7	1	0.8	3.1
	Hardness (CaCO3) (mg/L)	100		10	10	10	338	324	378	359	327	337	305	320
	Ammonia as N (mg/L)			0.05	0.02	0.02	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05
	Conductivity (us/cm)			3	2	2	780	695	773	712	728	701	755	755
	pH	8.5	6.5 - 8.5	0.1	N/A	N/A	7.7	8.0	7.88	8.14	7.84	8.11	8.18	8.08
Calculated Values	Anion sum (meq/L)			0.01			8.51	8.42		7.32	7.96	7.8	7.92	7.97
	Cation sum (meq/L)			0.01			7.96	7.36		8.19	7.5	7.83	7.08	7.55
	% Difference (%)			0.01	0.1	0.1	-6.68	6.8	2.6	0.2	3	0.2	5.6	2.7
	Langelier Index			0.0001			0.02	1.08	1.16	1.27	0.91	1.19	1.22	1.15
	Saturation pH (pH units)			0.01			7.68	6.92	6.72	6.87	6.93	6.92	6.96	6.93
	Silica (mg/L)				0.05	0.05	11.4	12.1	4.82	10.6	10.5	4.18	10.7	9.75

	Parameter (units)	122A 2003	122A 2008	122A 2009	122A 2010	122A 2011	122A 2012	122A 2013	122A 2014
Anions	Chloride (mg/L)	32.0	48.7	41.9	48.3	51.2	48.9	46.4	38.7
	Fluoride (mg/L)	<0.10	<0.05	<0.05	<0.05	<0.05	<0.05	<0.25	<0.10
	Nitrate as N (mg/L)	9.10	4.53	3.79	3.41	2.52	2.24	2.06	1.75
	Nitrite as N (mg/L)	<0.10	<0.05	<0.05	<0.05	<0.05	<0.05	<0.25	<0.10
	Phosphate-P (ortho) (mg/L)	<0.30	<0.10	<0.10	<0.10	<0.10	<0.10	<0.50	<0.20
	Sulphate (mg/L)	20.0	16.2	16.2	15.1	13.3	13	11.8	10.8
Metals	Aluminum (mg/L)	<0.01	0.964	0.004	<0.004	0.008	0.004	<0.004	<0.004
	Antimony (mg/L)	<0.005	<0.006	<0.006	<0.006	<0.003	<0.003	<0.003	<0.003
	Arsenic (mg/L)	<0.001	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Barium (mg/L)	0.07	0.089	0.049	0.058	0.05	0.051	0.047	0.042
	Beryllium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Bismuth (mg/L)	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Boron (mg/L)	<0.05	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
	Cadmium (mg/L)	<0.0001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Calcium (mg/L)	92.0	72.3	79.7	85.2	78.3	78.9	68.4	71.5
	Chromium (mg/L)	0.003	0.004	<0.003	<0.003	<0.003	0.006	<0.003	0.004
	Cobalt (mg/L)	<0.0008	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Copper (mg/L)	0.001	0.036	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Iron (mg/L)	0.07	1.86	<0.010	<0.010	<0.010	<0.010	0.012	<0.010
	Lead (mg/L)	<0.001	0.091	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Magnesium (mg/L)	26	22.6	24.6	26.1	23.8	24.2	20.4	21.5
	Manganese (mg/L)	<0.001	0.399	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Molybdenum (mg/L)	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Nickel (mg/L)	<0.002	<0.003	<0.003	0.004	<0.003	<0.003	<0.003	<0.003
	Phosphorus (mg/L)	<0.05	0.68	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Potassium (mg/L)	1.5	1.31	0.9	1.08	1.03	1.03	0.88	0.97
	Selenium (mg/L)	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
	Silver (mg/L)	<0.0001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Sodium (mg/L)	15	17.9	15.3	19.0	19.8	20.8	19.0	19.5
	Strontium (mg/L)	0.14	0.222	0.089	0.1	0.087	0.095	0.086	0.083
	Thallium (mg/L)	<0.0003	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
	Tin (mg/L)	0.003	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Titanium (mg/L)	<0.002	0.018	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Uranium (mg/L)	<0.005	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Vanadium (mg/L)	0.010	0.008	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Zinc (mg/L)	0.005	0.212	0.007	0.008	<0.005	<0.005	<0.005	<0.005
Wet Chemistry	Alkalinity (CaCO3) (mg/L)	280	247	242	263	244	256	252	265
	Bicarbonate (CaCO3) (mg/L)	279	247	242	263	244	251	252	265
	Carbonate (CaCO3) (mg/L)	<10	<5	<5	<5	<5	5	<5	<5
	Colour (TCU)	79	<5	<5	<5	<5	<5	<5	<5
	Total Organic Carbon (mg/L)	na	8.2	1.4	1.8	0.8	1	1.2	3.9
	DOC (mg/L)	0.9	1.7	1.3	1.3	0.7	1.1	1	3.9
	Hardness (CaCO3) (mg/L)	337	274	300	320	294	297	255	267
	Ammonia as N (mg/L)	<0.05	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.04
	Conductivity (us/cm)	720	597	637	636	615	619	644	638
	pH	7.5	7.99	8.04	8.18	7.99	8.31	8.22	8.06
Calculated Values	Anion sum (meq/L)	7.57	6.97		6.32	6.78	6.93	6.74	6.74
	Cation sum (meq/L)	7.42	6.28		7.25	6.75	6.86	5.94	6.21
	% Difference (%)	-2.00	5.2	0.4	0.5	0.2	0.5	6.3	4.1
	Langelier Index	-0.13	0.96	1.2	1.25	0.99	1.33	1.17	1.05
	Saturation pH (pH units)	7.63	7.03	6.84	6.93	7	6.98	7.05	7.01
	Silica (mg/L)	11.1	8.42	3.29	7.65	6.88	3.44	7.6	6.89

At or Exceeds ODWQS

Hanlon Creek Business Park - Groundwater Monitoring Program

Groundwater Quality

	Parameter (units)	ODWQS	PWQO	RDL			Monitoring Wells 123							124			125			126			127		
				2003	2008-10	2011-14	2003	2008	2009	2010	2011	2012	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014
Anions	Chloride (mg/L)	250		2.0	0.10	0.10 - 0.50	ns	4.22	3.86	3.7	3.94	4.18	4.24	294	324	290	120	4.2	254	175	185	229	131	163	232
	Fluoride (mg/L)	1.5		0.10	0.05	0.05 - 1.25	ns	1.22	1.39	1.1	1.38	1.4	1.28	<0.05	<0.5	<1.25	<0.05	1.18	<0.25	<0.05	<0.25	<1.25	<0.05	<0.25	<1.25
	Nitrate as N (mg/L)	10.0		0.10	0.05	0.05 - 1.25	ns	<0.05	<0.05	<0.05	<0.05	<0.05	<0.25	<0.05	<0.5	<1.25	1.06	<0.05	3.26	0.18	0.62	<1.25	1.4	1	<1.25
	Nitrite as N (mg/L)	1.0		0.10	0.05	0.05 - 1.25	ns	<0.05	<0.05	<0.05	<0.05	<0.05	<0.25	<0.05	<0.5	<1.25	<0.05	<0.05	<0.25	<0.05	<0.25	<1.25	<0.05	<0.25	<1.25
	Phosphate-P (ortho) (mg/L)			0.30	0.10	0.10 - 2.50	ns	<0.10	<0.10	<0.10	<0.10	<0.10	<0.50	<0.10	<1.0	<2.50	<0.10	<0.10	<0.50	<0.10	<0.50	<2.50	<0.10	<0.50	<2.50
	Sulphate (mg/L)	500		2.0	0.10	0.10 - 0.50	ns	21.7	22.1	22.1	22.9	23.5	22.4	46	44.3	39.4	23.2	22.5	20	16.4	15.6	16.6	16.6	16.1	16.7
Metals	Aluminum (mg/L)	0.1	0.075	0.01	0.004	0.004	ns	0.02	0.009	<0.004	0.009	0.007	<0.004	0.014	0.012	<0.004	0.021	0.005	<0.004	0.012	0.004	<0.004	0.019	0.005	<0.004
	Antimony (mg/L)	0.006	0.02	0.005	0.006	0.003	ns	<0.006	<0.006	<0.006	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Arsenic (mg/L)	0.025	0.005	0.001	0.003	0.003	ns	0.009	0.005	0.003	<0.003	<0.003	<0.003	0.004	<0.003	0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Barium (mg/L)	1.0		0.01	0.002	0.002	ns	0.067	0.076	0.07	0.07	0.075	0.063	0.163	0.107	0.113	0.065	0.065	0.062	0.054	0.046	0.053	0.057	0.043	0.054
	Beryllium (mg/L)		1.1	0.001	0.001	0.001	ns	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Bismuth (mg/L)			0.001	0.002	0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Boron (mg/L)	5.0	0.2	0.05	0.010	0.010	ns	0.02	0.017	0.015	0.019	0.02	0.016	0.014	<0.010	0.012	0.017	0.015	0.03	0.014	<0.010	0.012	0.013	<0.010	0.011
	Cadmium (mg/L)	0.005	0.0005	0.0001	0.002	0.001	ns	<0.002	<0.002	<0.002	<0.002	<0.001	<0.002	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Calcium (mg/L)	200		0.5	0.05	0.05	ns	45.9	56.6	56.8	50.5	50	53.2	139	157	148	92	54	110	64.9	73.9	59.5	87.9	90.2	75.9
	Chromium (mg/L)	0.05	0.0089	0.001	0.003	0.003	ns	<0.003	<0.003	<0.003	<0.003	0.003	<0.003	0.013	<0.003	<0.003	0.004	<0.003	<0.003	0.003	<0.003	<0.003	0.005	<0.003	<0.003
	Cobalt (mg/L)		0.0009	0.0008	0.001	0.001	ns	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Copper (mg/L)	1.0	0.005	0.001	0.003	0.002	ns	<0.003	<0.003	0.008	<0.003	<0.002	<0.003	0.002	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Iron (mg/L)	0.3	0.3	0.05	0.010	0.010	ns	0.113	0.1	0.082	0.177	0.043	0.057	0.223	3.42	2.92	<0.010	0.078	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
	Lead (mg/L)	0.010	0.025	0.001	0.002	0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Magnesium (mg/L)			0.5	0.05	0.05	ns	26.5	28.7	28.3	25.6	24.9	26.4	40.2	45.2	43.6	34.6	26.1	32.3	22.4	24.5	22.4	28.8	28.5	26.3
	Manganese (mg/L)	0.05		0.001	0.002	0.002	ns	0.004	0.003	<0.002	0.002	0.003	<0.002	0.197	0.222	0.204	0.057	<0.002	0.009	<0.002	<0.002	<0.002	0.003	<0.002	<0.002
	Molybdenum (mg/L)		0.04	0.001	0.002	0.001	ns	0.003	<0.002	<0.002	<0.002	0.002	<0.002	0.004	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Nickel (mg/L)		0.025	0.002	0.003	0.003	ns	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Phosphorus (mg/L)		0.01	0.05	0.05	0.05	ns	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Potassium (mg/L)			0.5	0.05	0.05	ns	1.42	1.24	1.26	1.15	0.99	1.11	1.14	0.96	0.83	1.63	1.1	1.89	2.13	2.05	1.49	1.14	1.06	1.22
	Selenium (mg/L)	0.01	0.1	0.005	0.004	0.004	ns	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
	Silver (mg/L)		0.0001	0.0001	0.002	0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Sodium (mg/L)	20		0.5	0.05	0.05	ns	4.6	4.13	4.61	3.66	3.8	4.36	82.5	100	103	50.5	3.88	124	89.5	94.1	111	64.7	75.5	119
	Strontium (mg/L)			0.001	0.005	0.005	ns	0.547	0.448	0.481	0.566	0.508	0.439	0.264	0.255	0.226	0.178	0.456	0.16	0.121	0.121	0.175	0.123	0.109	0.116
	Thallium (mg/L)		0.0003	0.0003	0.006	0.006	ns	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
	Tin (mg/L)			0.001	0.002	0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Titanium (mg/L)			0.002	0.002	0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Uranium (mg/L)	0.02	0.005	0.005	0.002	0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Vanadium (mg/L)		0.006	0.001	0.002	0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.003	<0.002	<0.002	<0.002	<0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Zinc (mg/L)	5	0.03	0.003	0.005	0.005	ns	0.023	0.007	0.007	<0.005	0.011	<0.005	0.02	0.024	<0.005	0.039	<0.005	<0.005	0.01	<0.005	0.023	0.031	0.008	0.009
Wet Chemistry	Alkalinity (CaCO3) (mg/L)	500		10	5	5	ns	235	223	237	223	233	228	313	318	332	309	225	306	213	229	210	288	277	267
	Bicarbonate (CaCO3) (mg/L)			10	5	5	ns	235	223	237	223	233	228	313	318	332	309	225	306	213	229	210	288	277	267
	Carbonate (CaCO3) (mg/L)			10	5	5	ns	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
	Colour (TCU)	5		1	5	5	ns	<5	<5	<5	<5	<5	<5	12	6	10	<5	<5	<5	<5	<5	<5	<5	<5	<5
	Total Organic Carbon (mg/L)				0.5	0.5	ns	0.5	1.8	0.8	0.5	2.2	0.6	25.8	7	6.8	5	1	33.5	5.3	1.9	3.8	4.2	3	3
	DOC (mg/L)	5		0.7	0.5	0.5	ns	0.5	1.6	0.9	0.5	1.2	0.7	13.7	5	6.1	3.8	1	20.7	4.7	1.6	3.6	2.3	2.6	3
	Hardness (CaCO3) (mg/L)	100		10	10	10	ns	224	260	258	232	227	242	513	578	549	372	242	408	254	285	241	338	343	298
	Ammonia as N (mg/L)			0.05	0.02	0.02	ns	<0.02	<0.02	0.03	0.04	0.04	0.07	0.17	0.12	0.22	<0.02	0.14	0.05	<0.02	<0.02	0.06	<0.02	<0.02	0.03
	Conductivity (us/cm)			3	2	2	ns	399	464	429	456	447	481	1440	1560	1570	896	479	1380	904	1040	1120	894	1040	1200
	pH	8.5	6.5 - 8.5	0.1	N/A	N/A	ns	8.2	8.28	8.15	8.05	8.18	8.1	8.07	7.71	8.08	8.25	8.25	7.67	8.23	8.14	8	8.11	8.09	8.01
Calculated Values	Anion sum (meq/L)			0.01			ns	5.27	5.03	4.58	5.12	5.34	5.21	15.5	16.4	15.6	10.1	5.15	13.9	9.55	10.2	11	9.9	10.5	12.2
	Cation sum (meq/L)			0.01			ns	4.7	5.39	5.39	4.81	4.73	5.05	13.9	15.9	15.5	9.67	5.05	13.6	9.03	9.85	9.68	9.6	10.2	11.2
	% Difference (%)			0.01	0.1	0.1	ns	5.7	3.5	0.3	3.1	6	1.6	5.6	1.5	0.5	2.3	1	1.2	2.8	1.6	6.4	1.6	1.9	4.6
	Langelier Index			0.0001			ns	1.09	1.21	1.11	0.93	1.07	1.01	1.38	1.07	1.44	1.45	1.16	0.88	1.07	1.07	0.81	1.21	1.18	1.02
	Saturation pH (pH units)			0.01			ns	7.11	7.07	7.04	7.12	7.11	7.09	6.69	6.64	6.64	6.8	7.09	6.79	7.16	7.07	7.19	6.9	6.91	6.99
	Silica (mg/L)				0.05	0.05	ns	15.6	6.59	15.1	14.4	15	14.3	13.2	14.2	12.9	4.65	16.1	8.05	1.38	4.08	2.6	3.37	6.75	6.25

At or Exceeds ODWQS

Hanlon Creek Business Park - Groundwater Monitoring Program

Groundwater Quality

	Parameter (units)	ODWQS	PWQO	RDL			Monitoring Wells 128			129			130			131			132		
				2003	2008-10	2011-14	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014
Anions	Chloride (mg/L)	250		2.0	0.10	0.10 - 0.50	177	225	426	116	128	139	ns	75.5	196	75.8	59.6	52.1	376	333	460
	Fluoride (mg/L)	1.5		0.10	0.05	0.05 - 1.25	<0.05	<0.25	<0.25	<0.05	<0.25	<0.25	ns	<0.25	<0.25	<0.05	<0.25	<0.10	<0.05	<0.5	<2.5
	Nitrate as N (mg/L)	10.0		0.10	0.05	0.05 - 1.25	0.17	1	1.76	4.5	4.58	4.11	ns	<0.25	0.45	1.41	1.2	1.44	2.42	1.93	2.54
	Nitrite as N (mg/L)	1.0		0.10	0.05	0.05 - 1.25	<0.05	<0.25	<0.25	<0.05	<0.25	<0.25	ns	<0.25	<0.25	<0.05	<0.25	<0.10	<0.05	<0.5	<2.5
	Phosphate-P (ortho) (mg/L)			0.30	0.10	0.10 - 2.50	<0.10	<0.50	<0.50	<0.10	<0.50	<0.50	ns	<0.50	<0.50	<0.10	<0.50	<0.20	<0.10	<1.0	<5.0
	Sulphate (mg/L)	500		2.0	0.10	0.10 - 0.50	56.7	48.7	41.9	39.4	33.7	26.6	ns	17	19.3	29.5	22.6	18.3	26.1	50.3	34.1
Metals	Aluminum (mg/L)	0.1	0.075	0.01	0.004	0.004	0.006	0.004	<0.004	0.01	0.007	<0.004	ns	0.004	0.241	<0.004	0.006	<0.004	0.005	0.006	<0.004
	Antimony (mg/L)	0.006	0.02	0.005	0.006	0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	ns	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Arsenic (mg/L)	0.025	0.005	0.001	0.003	0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	ns	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Barium (mg/L)	1.0		0.01	0.002	0.002	0.122	0.08	0.104	0.107	0.078	0.077	ns	0.062	0.078	0.045	0.032	0.033	0.123	0.087	0.146
	Beryllium (mg/L)		1.1	0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	ns	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Bismuth (mg/L)			0.001	0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Boron (mg/L)	5.0	0.2	0.05	0.010	0.010	0.01	<0.010	0.017	0.011	<0.010	<0.010	ns	0.013	0.014	0.017	<0.010	0.011	<0.010	<0.010	<0.010
	Cadmium (mg/L)	0.005	0.0005	0.0001	0.002	0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.001	<0.002	<0.002	<0.001	<0.002	<0.002
	Calcium (mg/L)	200		0.5	0.05	0.05	97.7	107	124	98.5	101	93.9	ns	80.8	85.2	70.2	80.9	81.9	85.8	91.5	113
	Chromium (mg/L)	0.05	0.0089	0.001	0.003	0.003	0.003	<0.003	0.005	0.004	<0.003	0.003	ns	<0.003	<0.003	0.007	<0.003	0.003	0.013	<0.003	<0.003
	Cobalt (mg/L)		0.0009	0.0008	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	ns	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Copper (mg/L)	1.0	0.005	0.001	0.003	0.002	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	ns	<0.003	<0.003	<0.002	<0.003	<0.003	<0.002	<0.003	<0.003
	Iron (mg/L)	0.3	0.3	0.05	0.010	0.010	0.05	<0.010	<0.010	<0.010	<0.010	<0.010	ns	<0.010	0.464	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
	Lead (mg/L)	0.010	0.025	0.001	0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	ns	<0.002	0.005	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Magnesium (mg/L)			0.5	0.05	0.05	38.8	37.9	39.9	33.3	33.5	31.5	ns	33.5	30.6	28.1	26.5	28	25.7	27.2	37.5
	Manganese (mg/L)	0.05		0.001	0.002	0.002	0.049	0.017	0.008	0.097	0.054	0.032	ns	<0.002	0.172	0.317	0.090	0.075	0.016	<0.002	<0.002
	Molybdenum (mg/L)		0.04	0.001	0.002	0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	ns	<0.002	<0.002	0.007	<0.002	<0.002	<0.001	<0.002	<0.002
	Nickel (mg/L)		0.025	0.002	0.003	0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	ns	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
	Phosphorus (mg/L)		0.01	0.05	0.05	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	ns	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Potassium (mg/L)			0.5	0.05	0.05	1.76	1.95	2.67	2.17	2.13	2.11	ns	0.71	1.2	2.02	1.36	1.08	1.56	1.64	2.3
	Selenium (mg/L)	0.01	0.1	0.005	0.004	0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	ns	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
	Silver (mg/L)		0.0001	0.0001	0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Sodium (mg/L)	20		0.5	0.05	0.05	63	94.4	175	45.4	55.5	63.4	ns	77.3	135	31.8	27.4	24.9	196	161	253
	Strontium (mg/L)			0.001	0.005	0.005	0.169	0.173	0.184	0.152	0.121	0.105	ns	0.221	0.197	0.116	0.115	0.096	0.118	0.143	0.164
	Thallium (mg/L)		0.0003	0.0003	0.006	0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	ns	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
	Tin (mg/L)			0.001	0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Titanium (mg/L)			0.002	0.002	0.002	0.012	<0.002	<0.002	<0.002	<0.002	<0.002	ns	<0.002	0.015	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Uranium (mg/L)	0.02	0.005	0.005	0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	ns	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	Vanadium (mg/L)		0.006	0.001	0.002	0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	ns	<0.002	0.002	<0.002	<0.002	<0.002	0.004	0.003	<0.002
	Zinc (mg/L)	5	0.03	0.003	0.005	0.005	0.008	0.007	0.014	0.015	0.029	0.007	ns	0.043	0.146	0.006	0.009	<0.005	0.021	0.019	0.018
Wet Chemistry	Alkalinity (CaCO3) (mg/L)	500		10	5	5	267	286	316	280	285	290	ns	395	352	263	289	300	286	276	274
	Bicarbonate (CaCO3) (mg/L)			10	5	5	267	286	316	280	285	290	ns	395	352	263	289	300	286	276	274
	Carbonate (CaCO3) (mg/L)			10	5	5	<5	<5	<5	<5	<5	<5	ns	<5	<5	<5	<5	<5	<5	<5	<5
	Colour (TCU)	5		1	5	5	<5	<5	<5	<5	<5	<5	ns	<5	<5	<5	<5	<5	<5	<5	<5
	Total Organic Carbon (mg/L)				0.5	0.5	4.3	2.4	6.5	13.8	3.3	38.9	ns	2.6	43.2	4.2	3	8.4	4.9	1.2	2.2
	DOC (mg/L)	5		0.7	0.5	0.5	3.3	1.2	5.6	6.5	2	37.7	ns	1.5	21.4	1.9	2.8	5.8	1.4	1.2	2.1
	Hardness (CaCO3) (mg/L)	100		10	10	10	404	423	474	383	390	364	ns	340	339	291	311	320	320	340	437
	Ammonia as N (mg/L)			0.05	0.02	0.02	<0.02	<0.02	0.07	0.06	<0.02	0.12	ns	<0.02	0.03	0.03	<0.02	0.04	<0.02	<0.02	0.03
	Conductivity (us/cm)			3	2	2	1040	1310	1890	896	1000	1060	ns	974	1260	724	768	745	1660	1610	1920
	pH	8.5	6.5 - 8.5	0.1	N/A	N/A	8.22	8.09	8.15	8.27	8.01	8.06	ns	8.1	8.07	8.26	8.18	8.01	8.05	8.13	8.06
Calculated Values	Anion sum (meq/L)			0.01			11.5	13.2	19.3	10	10.3	10.6	ns	10.4	13	8.11	8.02	7.95	17	16.1	19.3
	Cation sum (meq/L)			0.01			10.8	12.6	17.2	9.69	10.3	10.1	ns	10.2	12.7	7.25	7.44	7.5	15	13.8	19.8
	% Difference (%)			0.01	0.1	0.1	3	2.1	6	1.7	0.4	2.3	ns	1.1	1.3	5.6	3.7	2.9	6.5	7.5	1.1
	Langelier Index			0.0001			1.36	1.28	1.43	1.41	1.17	1.19	ns	1.37	1.26	1.28	1.27	1.13	1.11	1.2	1.24
	Saturation pH (pH units)			0.01			6.86	6.81	6.72	6.86	6.84	6.87	ns	6.73	6.81	6.98	6.91	6.88	6.94	6.93	6.82
	Silica (mg/L)				0.05	0.05	5.09	11.9	8.28	5.16	11.7	10.4	ns	5.84	6.29	10	9.38	7.97	10.1	10.8	9.91

At or Exceeds ODWQS

Hanlon Creek Business Park - Groundwater Monitoring Program

Groundwater Quality

	Parameter (units)	ODWQS	PWQO	RDL			Monitoring Wells 133			134			135			max	min	average
				2003	2008-10	2011-14	2012	2013	2014	2012	2013	2014	2012	2013	2014			
Anions	Chloride (mg/L)	250		2.0	0.10	0.10 - 0.50	99.4	91.5	78.1	anom	190	109	122	180	180	460	0.42	86.1
	Fluoride (mg/L)	1.5		0.10	0.05	0.05 - 1.25	<0.05	<0.25	0.17	<0.50	<0.25	<1.25	<0.05	<0.25	<1.25	1.4	0.05	0.45
	Nitrate as N (mg/L)	10.0		0.10	0.05	0.05 - 1.25	0.3	2.16	3.12	anom	0.32	<1.25	1.97	2.81	2.93	19.0	0.05	3.37
	Nitrite as N (mg/L)	1.0		0.10	0.05	0.05 - 1.25	<0.05	<0.25	0.26	<0.50	<0.25	<1.25	<0.05	<0.25	<1.25	1.0	0.08	0.45
	Phosphate-P (ortho) (mg/L)			0.30	0.10	0.10 - 2.50	<0.10	<0.50	<0.20	<1.00	<0.50	<2.50	<0.10	<0.50	<2.50	0.64	0.16	0.39
	Sulphate (mg/L)	500		2.0	0.10	0.10 - 0.50	34.2	19	15.5	79.5	40.7	37.1	59.4	21	19.8	89.4	4.54	24.2
Metals	Aluminum (mg/L)	0.1	0.075	0.01	0.004	0.004	0.024	0.007	<0.004	0.029	0.008	<0.004	0.037	0.007	<0.004	4.19	0.004	0.26
	Antimony (mg/L)	0.006	0.02	0.005	0.006	0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0	0	<0.003
	Arsenic (mg/L)	0.025	0.005	0.001	0.003	0.003	<0.003	<0.003	<0.003	0.006	<0.003	<0.003	<0.003	<0.003	<0.003	0.028	0.003	0.007
	Barium (mg/L)	1.0		0.01	0.002	0.002	0.084	0.086	0.075	0.357	0.069	0.064	0.066	0.065	0.1	1.190	0.031	0.117
	Beryllium (mg/L)		1.1	0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0	0	<0.001
	Bismuth (mg/L)			0.001	0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0	0	<0.002
	Boron (mg/L)	5.0	0.2	0.05	0.010	0.010	0.044	0.035	0.032	0.087	0.099	0.055	0.024	<0.010	<0.010	0.099	0.01	0.018
	Cadmium (mg/L)	0.005	0.0005	0.0001	0.002	0.001	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	0.020	0.0006	0.006
	Calcium (mg/L)	200		0.5	0.05	0.05	53.3	48.4	54.2	anom	88.1	67.3	80.2	80.7	77.1	157	22.9	80.4
	Chromium (mg/L)	0.05	0.0089	0.001	0.003	0.003	0.008	<0.003	0.004	anom	<0.003	<0.003	0.012	<0.003	<0.003	0.025	0.002	0.007
	Cobalt (mg/L)		0.0009	0.0008	0.001	0.001	0.002	0.001	<0.001	0.016	0.005	0.002	0.002	<0.001	<0.001	0.0419	0.001	0.012
	Copper (mg/L)	1.0	0.005	0.001	0.003	0.002	<0.002	<0.003	<0.003	0.01	0.005	<0.003	<0.002	<0.003	<0.003	0.167	0.002	0.034
	Iron (mg/L)	0.3	0.3	0.05	0.010	0.010	<0.010	<0.010	<0.010	<0.010	0.983	1.34	<0.010	<0.010	<0.010	12.2	0.012	1.585
	Lead (mg/L)	0.010	0.025	0.001	0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.591	0.001	0.115
	Magnesium (mg/L)			0.5	0.05	0.05	31.4	34.1	36	anom	42.3	35.2	32.7	26.4	26.8	45.2	19	27.8
	Manganese (mg/L)	0.05		0.001	0.002	0.002	0.404	0.239	0.204	0.018	0.638	0.196	0.385	0.043	<0.002	5.2	0.002	0.69
	Molybdenum (mg/L)		0.04	0.001	0.002	0.001	0.022	0.024	0.018	0.029	0.013	0.009	0.009	0.002	<0.002	0.029	0.002	0.007
	Nickel (mg/L)		0.025	0.002	0.003	0.003	0.004	<0.003	<0.003	0.059	0.008	<0.003	0.005	<0.003	<0.003	0.066	0.003	0.015
	Phosphorus (mg/L)		0.01	0.05	0.05	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	9.2	0.02	0.97
	Potassium (mg/L)			0.5	0.05	0.05	5.89	6.04	6.56	11.7	4.11	3.25	2.55	1.7	1.61	17.4	0.67	1.78
	Selenium (mg/L)	0.01	0.1	0.005	0.004	0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	0.006	0.005	0.005
	Silver (mg/L)		0.0001	0.0001	0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.0003	0.0001	0.0002
	Sodium (mg/L)	20		0.5	0.05	0.05	48.8	35.6	37.3	anom	58	79.5	50.8	75.8	91.5	253	3.00	42.9
	Strontium (mg/L)			0.001	0.005	0.005	0.177	0.184	0.161	1.37	0.229	0.142	0.176	0.136	0.121	2.410	0.073	0.296
	Thallium (mg/L)		0.0003	0.0003	0.006	0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	0	0	<0.006
	Tin (mg/L)			0.001	0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.006	0.002	0.003
	Titanium (mg/L)			0.002	0.002	0.002	<0.002	<0.002	<0.002	0.02	<0.002	<0.002	<0.002	<0.002	<0.002	0.081	0.002	0.019
	Uranium (mg/L)	0.02	0.005	0.005	0.002	0.002	<0.002	<0.002	<0.002	0.005	<0.002	<0.002	<0.002	<0.002	<0.002	0.01	0.002	0.003
	Vanadium (mg/L)		0.006	0.001	0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.003	<0.002	<0.002	0.047	0.002	0.007
	Zinc (mg/L)	5	0.03	0.003	0.005	0.005	0.036	0.013	<0.005	0.073	0.017	<0.005	0.048	0.012	0.009	2.14	0.005	0.110
Wet Chemistry	Alkalinity (CaCO3) (mg/L)	500		10	5	5	237	240	259	anom	272	289	269	268	270	395	180	270
	Bicarbonate (CaCO3) (mg/L)			10	5	5	237	240	259	anom	272	289	269	268	270	395	180	270
	Carbonate (CaCO3) (mg/L)			10	5	5	<5	<5	<5	<5	<5	<5	<5	<5	<5	18	5	10
	Colour (TCU)	5		1	5	5	<5	<5	<5	12	18	5	<5	<5	<5	65	5	15
	Total Organic Carbon (mg/L)				0.5	0.5	4.4	2.9	5.4	anom	18	4.2	5.7	2.4	1.9	50.4	0.5	5.6
	DOC (mg/L)	5		0.7	0.5	0.5	2.6	2.1	3.3	182	18	4.4	5.1	2.1	1.8	540	0.5	6.3
	Hardness (CaCO3) (mg/L)	100		10	10	10	262	261	284	anom	394	313	335	310	303	578	151	316
	Ammonia as N (mg/L)			0.05	0.02	0.02	0.19	0.33	0.17	<0.02	0.38	0.23	<0.02	<0.02	0.03	1.05	0.02	0.13
	Conductivity (us/cm)			3	2	2	764	751	751	anom	1160	962	920	1110	1060	1920	335	787
	pH	8.5	6.5 - 8.5	0.1	N/A	N/A	8.18	8.15	8.15	7.58	8.15	8.11	8	8.15	7.98	8.36	7.5	8.0
Calculated Values	Anion sum (meq/L)			0.01			8.28	7.93	7.96	anom	11.7	9.63	10.2	11.1	11.1	19.3	3.35	8.37
	Cation sum (meq/L)			0.01			7.52	6.94	7.46	anom	10.5	9.81	8.96	9.54	10.1	19.8	3.58	8.26
	% Difference (%)			0.01	0.1	0.1	4.8	6.7	3.2	2.4	5.2	0.9	6.4	7.5	4.8	8.3	-35.34	2.26
	Langelier Index			0.0001			1.11	1.09	1.16	2.18	1.29	1.21	1.06	1.18	1	2.18	-0.1	1.10
	Saturation pH (pH units)			0.01			7.07	7.06	6.99	5.4	6.86	6.9	6.94	6.97	6.98	7.9	5.4	6.93
	Silica (mg/L)				0.05	0.05	8.13	8.95	8.91	7.13	13.8	12.1	12.6	12.4	10.7	23.1	1.38	9.4

At or Exceeds ODWQS

Water AECOM

City of Guelph

Draft 2014 Hanlon Creek Tributary A Surface Water Monitoring Report

Prepared by:

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Project Number:

60265453

Date:

February 2015

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February 19 2015

Mr. Andrew Schiedel
Aquatic Biologist
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225 Labrador Drive, Unit 1
Waterloo, Ontario, N2K 4M8

Dear Mr. Schidel:

Project No: 60265453
Regarding: Draft 2014 Hanlon Creek Tributary A Surface Water Monitoring Report

We are pleased to provide a pdf copy of our 2014 Hanlon Creek Tributary A Surface Water Monitoring Report. If you have any questions or comments regarding this report, please contact the undersigned.

Sincerely,
AECOM Canada Ltd.

Nicole Weber, M.Sc. Ph.D, P.Eng.
Senior Manager, Water Resources

NW:am
Encl.

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AECOM Signatures

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1. Introduction

In anticipation of construction at the Hanlon Creek Business Park, AECOM was retained by the City of Guelph in 2003 to establish and carry out a surface water monitoring program at Hanlon Creek Tributary A to identify pre-construction flow and temperature characteristics. The surface water program has evolved since 2003 and is now included as the surface water monitoring component of the Consolidated Monitoring Program established for the Hanlon Creek Business Park (HCBP). Other components of this monitoring program include groundwater (Banks Groundwater) and ecological (NRSI). In August 2010, the Hanlon Creek Business Park Consolidated Monitoring Program (NRSI, AECOM, Banks Groundwater) was submitted to the City of Guelph. This monitoring plan included the location, parameters and naming convention for all surface monitoring works to be completed as part of the implementation of servicing and construction at the HCBP.

2. Background

2.1 Surface Water Monitoring Program

In 2003-2004 monitoring data was reported in separate memoranda to the City at the time of sampling and in the consolidated EIS prepared by Natural Resource Solutions Inc. (NRSI) for the Hanlon Creek Business Park in 2004. Monitoring continued in 2006 and 2007 with continuous temperature measurements at 6 stations between the outlet of the online pond (Road A) and 150 m upstream of Laird Road from May-December 2006 and August-December 2007. Depth and velocity were continuously measured at the Laird Road culvert from May-December 2006 and October-December 2007. Depth measurements were included at monitoring station HC-A(05) from October-December 2006 and August-December 2007. Sampling completed in 2006-2007 was summarized in a technical memorandum, submitted to the City of Guelph in February 2008.

The 2008 monitoring plan included temperature monitoring at the previous 6 stations along Tributary A and an additional temperature monitoring station (HC-A(14)) located downstream of the existing SWM pond (Pond 2) outlet. This additional station provides background information to identify the temperature impacts of proposed Ponds 1 and 2. Depth and velocity were monitored at the Laird Road culvert (HC-A(05)) and water depth was monitored at station HC-A(10). To establish a rating curve for HC-A(10), high flow measurements were collected in addition to the baseflow measurements. Through June-September 2008, sites were visited monthly to download data, perform maintenance, and collect baseflow measurements and water quality parameters (DO, pH, specific conductivity) at all stations. The depth/velocity instrument removed December 3, 2008. 2008 monitoring results were presented in a memorandum to the City of Guelph, dated February 3, 2009.

The 2009 monitoring plan included temperature monitoring at the 7 stations monitored in 2008. Temperature monitoring consisted of logging temperature readings every 15 or 30 minutes at the 7 site locations. Temperature loggers deployed during winter months were set at a 30 minute interval to ensure adequate memory would be available throughout the winter months. Loggers re-deployed during later months were set at a 15 minute interval. A continuous level/temp logger (HC-A(10)) and the depth and velocity monitoring equipment at HC-A(05) were used to monitor flow during 2009. During May-October 2009, sites were visited monthly to download data, perform maintenance, and collect baseflow measurements and water quality parameters (DO, pH, specific conductivity) at all stations. The flow/velocity instrument stopped logging data November 22nd due to battery failure and was removed from the culvert December 14, 2009. The remainder of the data loggers continues to collect continuous data at 30 minute intervals throughout the winter.

The 2010 monitoring plan included temperature monitoring at the 7 stations monitored in 2009 plus a new station, SR-1(01), which is located at the downstream end of a culvert crossing at Downy Road, just south of the intersection with Laird Road. Monitoring at the existing station HC-A(14) was also supplemented with the installation of a level logger. Temperature monitoring consisted of logging temperature readings every 15 minutes from April until December and every 30 minutes during the winter months at the 8 site locations. In addition, depth and velocity monitoring equipment was installed on April 8, 2010 at the Laird Road culvert (HC-A(05)). During May-October 2010, sites were visited monthly to download data, perform maintenance, and collect baseflow measurements and water quality parameters (DO, pH, specific conductivity) at all stations. High flow measurements were collected to develop rating curves for HC-A(10) and HC-A(14).

During the 2011 monitoring year, a number of additional stations were installed in Tributary A at the start of the monitoring year. Monitoring in the stormwater management facilities was initiated as the facilities were completed to a point where it was feasible to install the monitoring equipment without risk of damage due to construction activities. During the 2012 monitoring year, Ponds 1, 2 and 4 were functioning as stormwater management facilities and all monitoring stations were installed in Tributary A. During the 2014 monitoring year all ponds continued to function as stormwater management facilities and all monitoring stations were installed in Tributary A. A small number of stations were relocated based on recommendations from the 2012 monitoring report to improve data collection. All stations used during the 2012 and 2013 monitoring year were used during the 2014 year as no new stations were deemed necessary.

Table A and **Table B** summarize the monitoring completed at each of the sites during the 2014 monitoring season. Monitoring station locations are illustrated in Figure 2-1.

During the winter months, the telemetry stations were removed and replaced with temperature/depth loggers set to record at 30 minute intervals. Telemetry stations were reinstalled in May 2014. Temperature/depth loggers were removed during the winter months from stations where the flow is intermittent. This was done to prevent damage from occurring to the logger.

Table A: Tributary A Monitoring Stations

Station ID	Station ID Prior to 2010	Data Collected*	Date installed	Notes
HC-A(03)		Temperate, Depth, Turbidity	March 2011	Turbidity sensor replaced for 2012
HC-A(04)	**1**	Temperature, Depth	March 2011	
HC-A(05)	**"FLOW"**	Area/velocity	--	Area/velocity meter was not installed to do issues with sedimentation in the culvert during the 2010 monitoring year.
HC-A(06)	**2**	Temperate, Depth, Turbidity	March 2011	Turbidity sensor replaced for 2012
HC-A(08)	**3**	Temperature	May 2006	
HC-A(09)	**4**	Temperature	May 2006	
HC-A(10)	**5**	Temperature, Depth	May 2006	
HC-A(11)	**6**	Temperate, Depth, Turbidity	March 2011	Turbidity sensor replaced for 2012
HC-A(12)	**7**	Temperature, Depth	April 2011	
HC-A(13)		Temperature, Depth	March 2011	
HC-A(14)		Temperate, Depth, Turbidity	March 2011	Turbidity sensor replaced for 2012
SR-1(01)		Temperature, Depth	June 2010	

*Note: prior to 2010, only Station HC-A(10) (or Station #5) was monitored for level in addition to temperature. The HC-A(05) ("FLOW") station was monitored for flow. All other stations collected only temperature data prior to 2010.

Figure 2-1: Monitoring Station locations

Table B: Pond Monitoring Stations

Station	Data Collected	Date installed	Location
		Pond 1	
HC-P1(01)	Temperature	September 2011	In pond close to bottom
HC-P1(02)	Temperature	September 2011	In pond near mid-depth
HC-P1(03)	Temperature	September 2011	In pond at surface
HC-P1(04)	Temperature, Depth	September 2011	Inlet
HC-P1(05)	Temperature, Depth	September 2011	Inlet
HC-P1(06)	Temperature, Depth	June 2011	Outlet
HC-P1(07)	Temperature	June 2011	Cooling trench outlet
HC-P1(08)	Temperature	June 2011	Cooling trench outlet
		Pond 2	
HC-P2(01)	Temperature	April 2011	In pond close to bottom
HC-P2(02)	Temperature	April 2011	In pond near mid-depth
HC-P2(03)	Temperature	April 2011	In pond at surface
HC-P2(04)	Temperature, Depth	April 2011	Inlet
HC-P2(05)	Temperature, Depth	August 2012	Inlet
HC-P2(06)	Temperature, Depth	June 2011	Inlet
HC-P2(07)	Temperature, Depth	April 2011	Outlet
		Pond 4	
HC-P4(01)	Temperature	October 2011	In pond close to bottom
HC-P4(02)	Temperature	November 2011	In pond near mid-depth
HC-P4(03)	Temperature	November 2011	In pond at surface
HC-P4(04)	Temperature, Depth	August 2012	Inlet
HC-P4(05)	Temperature, Depth	October 2011	Outlet
HC-P4(06)	Temperature	October 2011	Cooling trench outlet

Influent and effluent water quality monitoring of SWM pond inlets and outlets and Tributary A downstream of the SWM ponds was also monitored as per MOE CofA 1384-7QFPZQ requirements. Ponds 1, 2 and 4 were all sampled during the 2014 monitoring program.

During May-December 2014, sites were visited monthly to download data, perform maintenance, and collect baseflow measurements and water quality parameters (DO, pH, specific conductivity) at all in-stream stations. High flow measurements were collected for HC-A(03), HC-A(04), HC-A(06), HC-A(10), HC-A(11), HC-A(12), HC-A(13), and HC-A(14) to develop a rating curve. Monitoring reports from 2014 site visits are included in **Appendix A**.

2.2 Site Description

Station HC-A(03) is located approximately in the headwaters of the site, about 10 m upstream of Pond 4 in a partially forested area. Station HC-A(04) is located approximately 75 m downstream of Pond 4 and 150 m upstream of Laird Road in a partially forested area. The stream then passes through an open area and under Laird Road. HC-A(06) is located approximately 100 m downstream of Laird Road. The stream passes through a cedar wetland in which HC-A(09) is located. HC-A(08) is located in the same cedar wetland on a tributary of the main branch of the creek (Hanlon Tributary A1). HC-A(10) is located approximately 50 m downstream of the confluence of the main branch and the tributary and just upstream of the 'Road A' crossing. HC-A(11) is located at the downstream end of 'Road A' culvert. The stream then passes through another cedar wetland area, and HC-A(12) is located in an open wetland area at the outlet of cedar wetland and upstream of Pond 1. HC-A(13) is approximately 200 m downstream of HC-A(12) and immediately downstream of the outlet of Pond 1 in an open field. HC-A(14) is located at the downstream end of the study site, approximately 150 m upstream of Teal Drive.

2.3 Site Construction

In July of 2009 tree cover upstream of stations HC-A(11), HC-A(14) and the online pond and downstream of station HC-A(10) was removed as part of the initial clearing for the Road A culvert construction. In the summer of 2010 construction of the site began with the works being completed at the culvert crossing in August. During the 2011 year, construction of the Phase 1 site was completed. Construction at the Phase 2 site was still underway at the end of 2011; at that time clearing and earthworks had been completed. By early 2012, the construction of the infrastructure including roads and utilities had been completed for both Phase 1 and 2. The first lot level development began in Phase 1 in May 2012. No buildings were constructed in Phase 2 during 2012. Development continued in 2013 and 2014 with construction of some buildings and related parking areas occurring in Phase 1. Construction of the Laird Road overpass occurred in the Phase 2 lands in 2013.

2.4 Data Gaps

During the 2014 sampling year, winter stream conditions, and equipment malfunctions produced data gaps in the continuous monitoring data. **Table C** outlines time periods and monitoring parameters unavailable for the associated station. Weather data from the Guelph Turfgrass Institute and the Elora Research Station were provided by the University of Guelph.

In 2014, numerous errors occurred in some of the continuous monitoring equipment due to a faulty shuttle. The data for HC-P1(06) was not collected in 2014 as it was not replaced after it went missing numerous times in early 2014.

Table C: Data Gaps in Logger Files

Station	Parameter	Data Gaps
Tributary A		
HC-A(03)	Temperature/ Water Level Turbidity	Apr 17 – Apr 18
HC-A(04)	Temperature/ Water Level	Apr 17 – Apr 18
HC-A(06)	Temperature/ Water Level Turbidity	Apr 2 – May 6
HC-A(08)	Temperature	Feb 28 – May 6, June 11 – July 25, Aug 30 – Sept 5, Oct 11 – Dec 31
HC-A(09)	Temperature	No Gap
HC-A(10)	Temperature/ Water Level	May 6 – May 7
HC-A(11)	Temperature/Water Level/ Turbidity	No Gap
HC-A(12)	Temperature/ Water Level	May 6 – May 7
HC-A(13)	Temperature/ Water Level	May 6 – May 7
HC-A(14)	Temperature/ Water Level Turbidity	March 3 - March 7
SR-1(1)	Temperature/Water Level	Jan 1 – Apr 17
Pond 1		
HC-P1(01)	Temperature	No Gap
HC-P1(02)	Temperature	No Gap
HC-P1(03)	Temperature	No Gap
HC-P1(04)	Temperature/ Water Level	Aug 22 – Oct 10
HC-P1(05)	Temperature/ Water Level	No Gap
HC-P1(06)	Temperature/ Water Level	Does not exist- Stolen several times and did not replace it for 2014 season.
HC-P1(07)	Temperature	Apr 17 – Apr 18, July 18 – July 25
HC-P1(08)	Temperature	July 18 – July 25, Nov 7 – Nov 8
Pond 2		
HC-P2(01)	Temperature	May 5 – July 18
HC-P2(02)	Temperature	May 5 – July 18
HC-P2(03)	Temperature	Jan 24 – July 18
HC-P2(04)	Temperature/ Water Level	Jan 1- May 5
HC-P2(05)	Temperature/ Water Level	Jan 1- May 5
HC-P2(06)	Temperature/ Water Level	Jan 1- May 5
HC-P2(07)	Temperature/ Water Level	Jan 1- May 5
Pond 3		
HC-P4(01)	Temperature	Apr 17 – Apr 18
HC-P4(02)	Temperature	Mar 3 – Apr 17 May 23 – July 18 Sept 27 – Oct 9 Nov 14 – Dec 8
HC-P4(03)	Temperature	Dec 8 – Dec 9
HC-P4(04)	Temperature/ Water Level	No Gap
HC-P4(05)	Temperature/ Water Level	Apr 2 – Apr 17
HC-P4(06)	Temperature	No Gap

3. In-stream Temperature Monitoring

The locations of the temperature monitoring stations for 2014 are shown in **Figure 2-1**. Station descriptions are included in Section 2.2. The temperature loggers (HOBO Pendant Temperature/Light Logger and HOBO 12-bit Temperature Smart Sensors) and level/temperature loggers (HOBO U20 Water Level Data Logger) were placed in the creek secured to a steel stake driven into the substrate. Data was collected in 30 minute intervals during the winter months and 15 minute intervals for the remainder of the year.

A plot of the continuous temperature monitoring throughout the entire year is included in

Figure 3-3. Monthly plots of stream and hourly air temperature data from the Guelph Turfgrass Institute Station are included in **Appendix B**. These plots show the daily pattern of temperature variation, with temperatures increasing during the day and decreasing at night.

Limited data is available for the 2014 winter season due to logger failure and data collection gaps. In comparison to previous monitoring records, station HC-A(10) has shown the greatest fluctuation in daily temperatures during winter months. Stations HC-A(04), HC-A(06) and HC-A(08) also showed significant fluctuations and HC-A(09) maintained the highest temperatures, generally above 3°C.

During summer months the stations which are more exposed such as HC-A(10), HC-A(12), HC-A(13) and HC-A(14); and those with a wider flow channel and shallower depths (HC-A(09)) show the highest daily variation in temperature as there is greater opportunity for solar radiation impact. Station HC-A(08) shows the lowest temperatures and daily temperature variation during the summer, indicating the presence of groundwater inputs.

The ability of a stream to support a cold-water fish species is often defined by the temperatures throughout the summer (July and August) and autumn (mid October – end of November) months. The 2009 Hanlon Business Park Stream Temperature Impact Report (AECOM, 2009) provided a summary of reach based statistical stream temperature modeling results for future mitigated site conditions. This summary included target daily averages, maximums, minimums, the number of hours target temperatures were exceeded and exceedance frequencies during both the summer and autumn. A summary comparison of overall modeled existing and future mitigated conditions of average temperature conditions throughout the creek were also included in the modeling report. The same statistical analysis applied to the HSP-F modeling results has been applied to the 2014 data and is included in Table D and Table E where sufficient data are available. To monitor the changes to Hanlon Creek over time, a comparison of 2014 data to historical conditions has been included in **Appendix C**.

Note that the Hanlon Creek Business Park Consolidated Monitoring Plan recommends:

1. Any single temperature exceedance of 22°C is analyzed in an annual temperature and flow monitoring report, including an investigation of the cause of the exceedance and recommendations for contingency measures as warranted. The investigation should consider the frequency, duration and spatial distribution of the exceedance.
2. Any single temperature exceedance of 24°C triggers an investigation commencing within 2 days of acquiring the information. This investigation should consider the frequency, duration and spatial distribution of the exceedance, seek to identify the cause of the temperature exceedance, and provide recommendations for adaptive management measures as warranted. If contingency measures are warranted, the design and implementation of selected measures should be completed as soon as possible. At the latest, the selected measures should be implemented in the year following the exceedance of 24°C.

No exceedances of 24°C were recorded in 2010, in comparison a single occurrence of 22°C was recorded at station HC-A(14) in 2009. In 2011, exceedances above 24°C were again observed, with eight of ten stations experiencing temperature exceedances. 2012 recorded the highest number of exceedances to date within the main branch of Hanlon Creek. It was noted that, unlike previous years, the temperature was exceeding in the headwater reaches of the creek, downstream of Pond 4 as opposed to the exceedances occurring in the furthest downstream reaches. These issues were noted in July of 2012 and the RAAP team was assembled to try and address the cause of the exceedances. It was determined that the cause of the temperature exceedances was the continuous discharge of Pond 4. Mitigation measures were put into place with a goal to decrease the quantity and temperature of water entering Tributary A via pond 4. The weir in pond 4 was raised during the summer season in order to limit outflow and groundwater input. Vegetation along the cooling trench was installed during the fall with hopes it would act as a cooling agent once it became established.

In 2014, overall temperature conditions was similar to the temperature level to 2013. Fewer exceedance events occurred in 2014 compared to 2013. Temperatures remained higher at stations found farthest downstream while the trend of increasing temperatures at reaches downstream of pond 4, observed in 2012, also continued. HC-A(04), HC-A(06) and HC-A(09) all saw extended periods above 24°C caused in part by the continuous discharge from pond 4, but lesser extended periods compared to 2013.

Water temperature exceedances decreased in 2014 from 2012 and 2013; however temperatures were still above the ideal habitat conditions documented for brook trout in the *Hanlon Creek Business Park Stream Temperature Impact Report Continuous Modeling with HSP-F* (AECOM, 2009). The greatest contributor to stream temperature increases was the continuous discharge of warm water into the headwater of the creek from Pond 4. Below average precipitation levels noted in **Table H**, as well as dry periods during the month of August helped increase stream temperatures. Air temperatures for the summer months compared to previous monitoring years and the Canadian Climate Normals are given in **Table F** and were observed to be at or slightly above average.

A comparison between the numbers of 24°C exceedance events per monitoring site to the average summer temperatures for 2014 has been provided in **Figure 3-1**. In addition, a comparison between the recorded number of hours in stream temperatures exceeded 19°C to the average summer temperatures has been given in **Figure 3-2**.

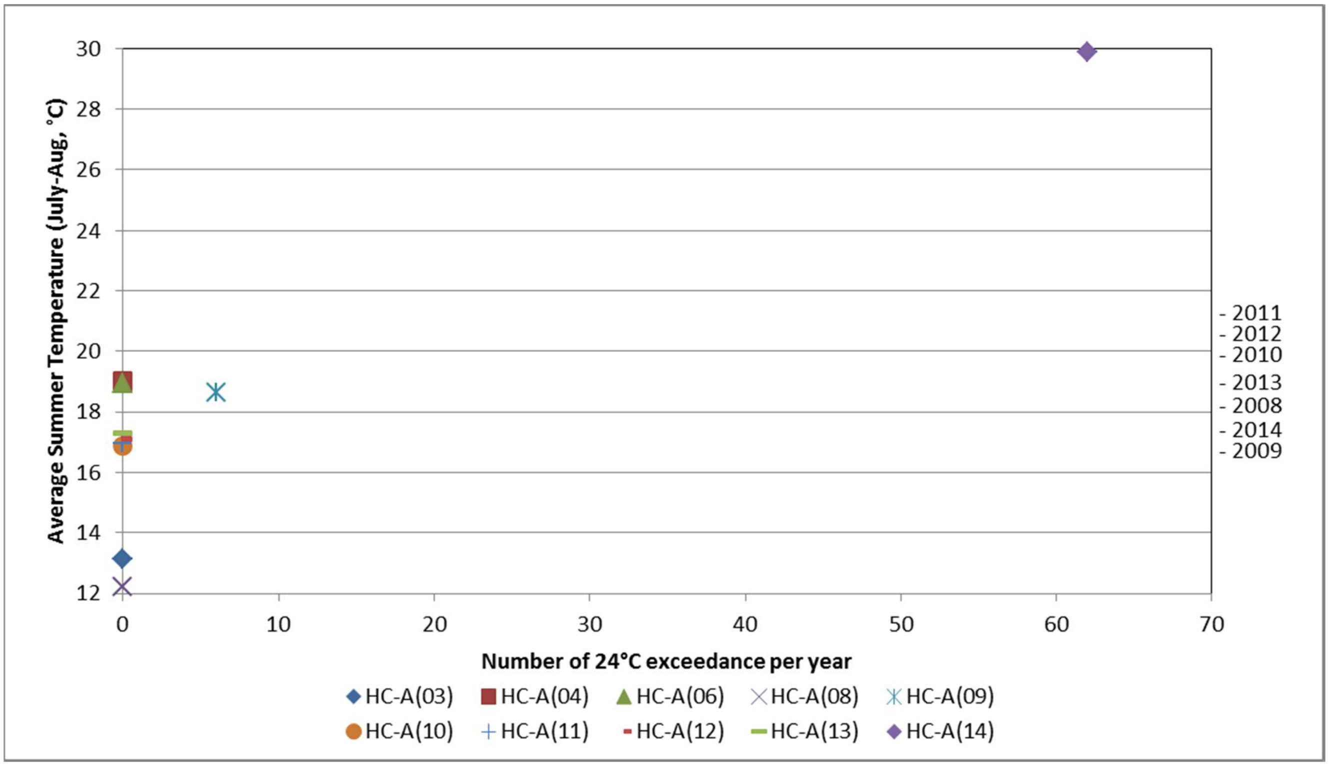

Figure 3-1: A comparison between the number of 24°C exceedance events per monitoring site to the average summer temperatures for 2014.

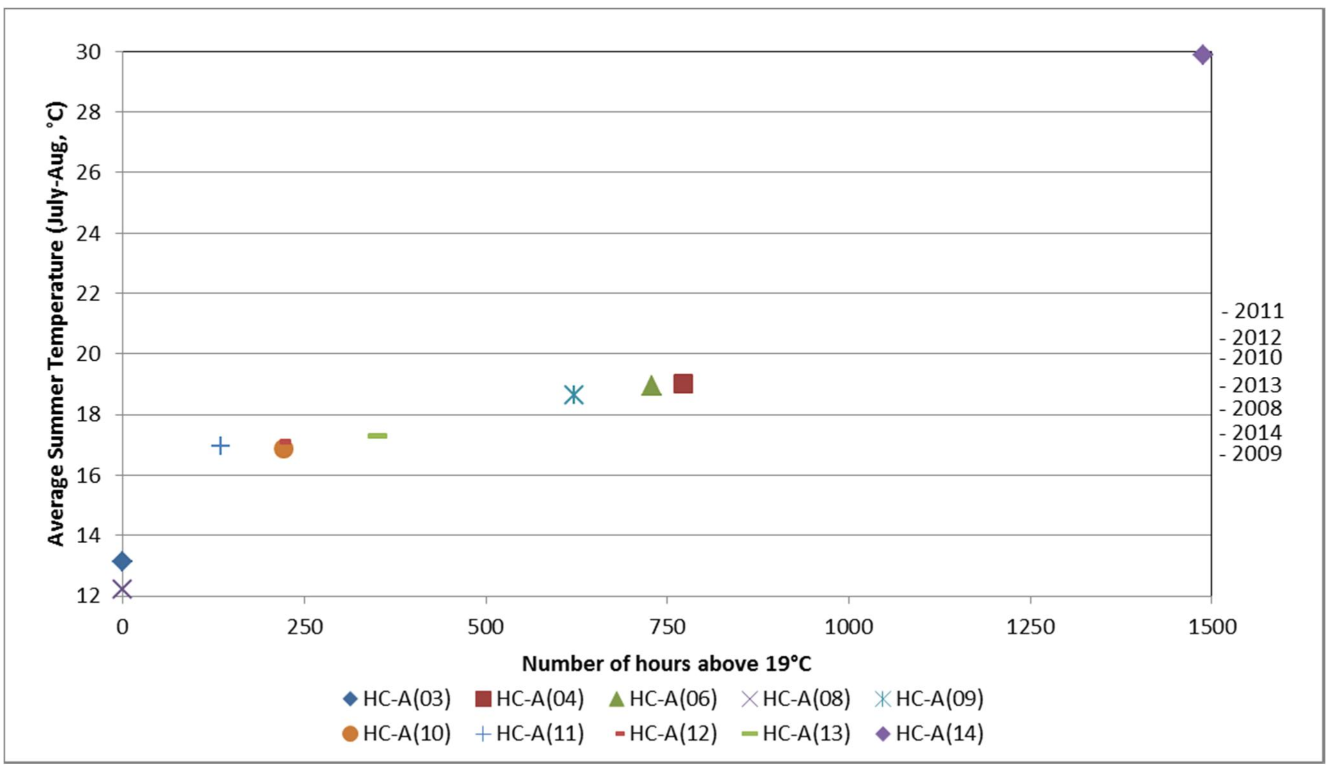

Figure 3-2: A comparison between the recorded number of hours in stream temperatures exceeded 19°C to the average summer temperatures

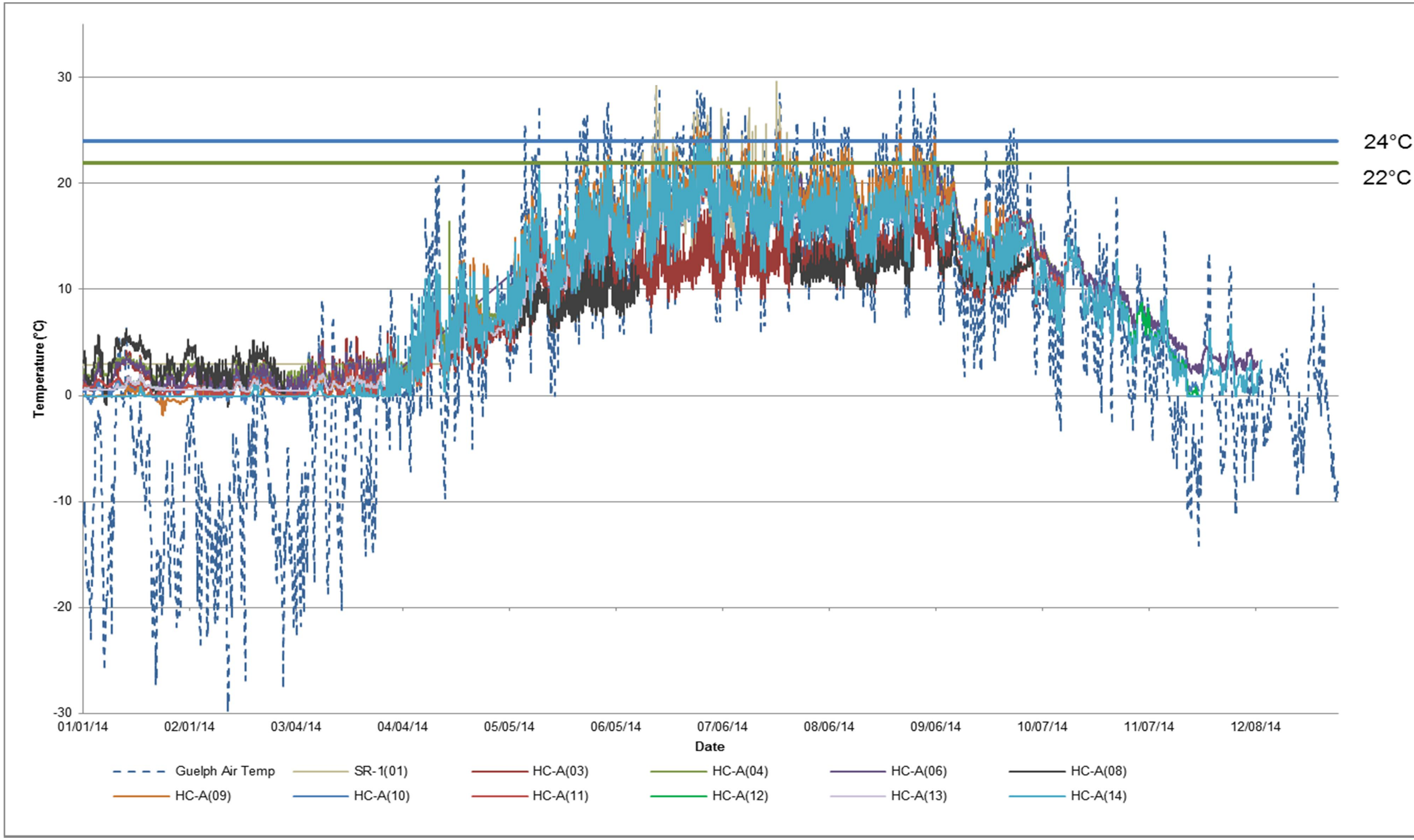

Figure 3-3: Hanlon Creek Temperature Monitoring –January –December 2012

Table D: Summer (July-August) Temperature Summary

Station	Modeled Values[1]	HC-A(03)	HC-A(04)	HC-A(06)	HC-A(08)	HC-A(09)	HC-A(10)	HC-A(11)	HC-A(12)	HC-A(13)	HC-A(14)	SR-1(01)
Summer (July-August) average maximum (ºC)	14.5 - 19.9	15.68	20.03	20.42	8.55	21.80	19.63	18.63	19.18	20.12	31.63	22.87
Summer (July-August) average (ºC)	12.5 - 14.5	13.13	19.02	18.95	12.21	18.62	16.88	16.97	17.11	17.29	29.89	17.12
Summer (July-August) average minimum (ºC)	9.0 - 12.0	11.23	18.06	17.79	6.17	16.36	14.82	15.60	15.41	14.92	28.61	13.21
Maximum 3-day mean (ºC)	14.0 - 19.0	14.72	20.27	20.10	13.38	20.43	18.74	18.89	19.36	19.52	31.21	19.29
Maximum 7-day mean (ºC)	13.0 - 17.0	14.28	19.61	19.51	12.95	19.47	17.76	17.87	18.38	18.37	30.71	18.49
Maximum 7-day mean of daily maximums (ºC)	15.0 - 23.5	16.88	21.05	21.58	15.53	23.03	21.20	19.88	21.12	21.76	32.82	24.89
	Temperature Exceedance over 19°C for July and August											
Hours over 19°C	0 - 130	0	771	729	0	622	222	136	218	350	1488	381
Percent of Time over 19°C	0 - 9%	0%	52%	49%	0%	42%	15%	9%	15%	24%	100%	26%
Frequency of Exceedance over 19°C (Days)	0 - 27	0	53	56	0	60	40	23	28	46	62	58
Average Duration of Event Over 19°C (h)	3 - 6	0	16.76	12.35	0	10.90	5.28	5.89	7.52	7.61	1488.00	5.44
Maximum duration of event over 19°C (h)	<<130	0.00	98.75	59.50	0.00	37.25	16.00	17.75	27.25	26.25	1488.00	16.00
	Temperature Exceedance over 22°C for July and August											
Hours over 22°C		0	4	5	0	106	10	0	11	28	1488	121
Percent of Time over 22°C		0%	0%	0%	0%	7%	1%	0%	1%	2%	100%	8%
Frequency of Exceedance over 22°C (Days)		0	2	2	0	26	4	0	3	6	62	38
Average Duration of Event Over 22°C (h)		0	0.95	1.01	0	2.66	1.97	0	2.06	2.87	744.13	2.09
Maximum duration of event over 22°C (h)	<<130	0.00	2.25	2.50	0.00	9.75	5.25	0.00	4.75	8.75	1488.00	7.75
	Temperature Exceedance over 24°C for July and August											
Hours over 24°C	0 -3.2	0	0	0	0	14	0	0	0	0	1488	44
Percent of Time over 24°C	0 - 0.21%	0%	0%	0%	0%	1%	0%	0%	0%	0%	100%	3%
Frequency of 24°C Exceedance (Days)		0	0	0	0	6	0	0	0	0	62	19
Average Duration of Event Over 24°C (h)		0	0	0	0	2.25	0	0	0	0	1488.00	1.81
Maximum duration of event over 24°C (h)	<3.2	0.00	0.00	0.00	0.00	4.50	0.00	0.00	0.00	0.00	1488.00	4.75

[1] Modeled range referees to the results of the Hanlon Creek Business Park Stream Temperate Impact Report Continuous Modeling with HSP-F (AECOM, 2009)

Table E: Fall Temperature Summary

Station	Modeled Range	HC-A(03)	HC-A(04)	HC-A(06)	HC-A(08)	HC-A(09)	HC-A(10)	HC-A(11)	HC-A(12)	HC-A(13)	HC-A(14)	SR-1(01)
	Mid October to End of November											
Max Temp. (°C)	11.9 - 13.0	13.21	13.17	13.56	13.67	n/a	15.57	14.71	14.84	14.13	14.52	14.52
Frequency of 11°C Exceedance (days)	2.1 - 5.6	5.00	5.00	9.00	10.00	n/a	7.00	7.00	7.00	5.00	5.00	3.00
Hours Over 11°C	16 - 27	83.75	78.25	155.00	138.75	n/a	104.25	96.75	96.50	93.25	93.50	46.50
Average Hrs. Over 11°C per Event	4.8 - 5.9	27.92	26.08	31.00	17.34	n/a	20.85	19.35	16.08	31.08	31.17	15.50
Maximum duration of event over 11°C (h)	5.9	67.5	44.00	105.00	95.75	n/a	80.25	78.50	78.00	79.50	78.75	39.00
	November Only											
Max Temp. (°C)	9.3 - 11.3	9.77	8.78	8.79	n/a	8.68	9.37	9.44	8.98	8.88	8.98	n/a
Frequency of 11°C Exceedance (days)	0.4 - 2.0	0.00	0.00	0.00	n/a	0.00	0.00	0.00	0.00	0.00	0.00	n/a
Hours Over 11°C	0.4 - 11.3	0.00	0.00	0.00	n/a	0.00	0.00	0.00	0.00	0.00	0.00	n/a
Average Hrs. Over 11°C per Event	1.0 - 10.8	0.00	0.00	0.00	n/a	0.00	0.00	0.00	0.00	0.00	0.00	n/a
Maximum duration of event over 11°C (h)	10.8	0.00	0.00	0.00	n/a	0.00	0.00	0.00	0.00	0.00	0.00	n/a

Table F: Comparison of Monthly Ambient Air Temperatures to the Canadian Climate Normals

	Daily Average (°C)					Average Daily Maximum (°C)					Average Daily Minimum (°C)				
	May	Jun	Jul	Aug	Sep	May	Jun	Jul	Aug	Sep	May	Jun	Jul	Aug	Sep
Climate Normals[1]	12.3	16.9	19.7	18.6	14.1	18.6	23.3	25.9	24.5	19.8	6.0	10.6	13.5	12.6	8.4
2007	12.7	18.3	18.5	19.3	15.8	20.5	25.9	26	26.5	23.7	4.9	10.6	10.9	12.1	7.8
2008	10.1	17.9	19.7	17.5	14.9	16.3	23.3	25.7	23.7	21.1	3.9	12.5	13.6	11.2	8.7
2009	11.2	15.9	16.5	17.4	13.5	18	21.7	22.1	23.7	20	4.2	10	10.8	11	7
2010	n/a	n/a	20.3	19.8	14.1	n/a	n/a	26.4	26.1	19.6	n/a	n/a	14.2	13.3	8.5
2011	12.7	16.7	21.4	19.3	15.2	17.7	22.7	28.6	25.8	20.9	7.8	10.6	14.1	12.6	9.6
2012	15.2	18.6	22	19.3	14.4	22.8	25.2	30.1	26.6	21.1	7.5	12	13.9	11.9	7.6
2013	13.5	16.9	19.9	18	13.7	20.4	22.3	25.3	24.5	20.2	6.2	11.4	14.5	11.4	7.1
2014	12.3	17.8	17.6	17.6	14.1	18.5	24.6	23.6	23.6	20.5	5.9	10.9	11.5	11.4	7.7

[1]Data is taken from Canadian Climate Normals 1971-2000 for the Guelph Arboretum, 2007 to 2014 data was collected at the Guelph Turfgrass station

The method described in Stoneman and Jones (1996) later revised by C. Chu *et al.*(2009) is used to determine the temperature regime. Each station is based on a comparison of daily maximum air temperature and maximum in-stream water temperature measured between 16:00 and 18:00 during summer months (July 1 – August 31) when maximum daily air temperatures exceed 24.5°C. A nomograph is then used to classify results based upon water thermal characteristics of coldwater, cold-coolwater, coolwater, cool-warmwater and warmwater. **Appendix D** includes graphical representation of this analysis. Table G summarizes the thermal regime classification associated with each station within the study area. The 2014 classification shows cooler conditions, similar to those of 2013, 2011 and prior.

Table G: Temperature Classification Summary

	Based on C. Chu *et al.* (2009)							Based on Stoneman and Jones (1996)	
Station	**2014**	**2013**	**2012**	**2011**	**2010**	**2009**	**2008**	**2007**	**2006**
HC-A(03)	Cool-Cold	Cool-Cold	Cool	Cool	n/a	n/a	n/a	n/a	n/a
HC-A(04)	Cool	Cool-Warm	Warm	Cool	Cool	Cool-Cold	Cool-Cold	Cold	Cold
HC-A(06)	Cool-Warm	Cool-Warm	Warm	Cool	Cool	Cool-Cold	Cool-Cold	Cool	Cool
HC-A(08)	Cold	Cold	Cool-Cold	Cold	Cold	Cold	Cold	Cold	Cold
HC-A(09)	Cool-Warm	Cool-Warm	Warm	Cool-Warm	Cool-Warm	n/a	Cool	Cold	Cool
HC-A(10)	Cool-Warm	Cool-Warm	Cool-warm	Cool-Warm	Cool-Cold	n/a	Cool-Cold	Cool	Cool
HC-A(11)	Cool	Cool	Cool-Warm	Cool	Cool	Cool-Warm	Cool	Warm	Warm
HC-A(12)	Cool	Cool	Warm	Cool-Warm	n/a	n/a	n/a	n/a	n/a
HC-A(13)	Cool-Warm	Cool	Warm	Cool-Warm	n/a	n/a	n/a	n/a	n/a
HC-A(14)	Cool-Warm	Cool-Warm	Warm	Cool-Warm	Cool-Warm	Cool	Cool	n/a	n/a

4. In-stream Flow Monitoring

Nine flow monitoring stations were installed along Hanlon Creek. The depth/velocity meter (ISCO 2100) was not installed in 2011, 2012, 2013, and 2014 due to high sedimentation at HC-A(05) in previous years producing unreliable data.

A depth logger (HOBO U20-001-001 Water Level logger) was used to monitor water levels at HC-A(04), HC-A(10), HC-A(12), HC-A(13) and SR-1(01) throughout 2014. Depth measurements were also collected at telemetry monitoring (Instrumentation Northwest, PS9800) stations HC-A(03), HC-A(06), HC-A(11) and HC-A(14). Up to nine flow measurements were taken between April 29th and December 1st 2014 at each station using a FlowTracker Handheld-ADV® (Acoustic Doppler Velocimeter). Flow measurements were not able to be collected at SR-1(01) due to very low flows or dry conditions at the culvert outlet. The flow values were used to develop stage (level) - discharge relationships and establish a rating curve for each station as shown in **Figure 4-2** to **Figure 4-9**.

The following issues were experienced with the stations over the course of the 2014 monitoring year:

- On April 29th 2014, HC-A(14) station was moved downstream of the 2013 and previous year's location due to a bank failure/sedimentation at the cross section. The flow was divided and resulted in faulty flow measurements. A new cross section was created approximately 5m downstream of the original section.

Figure 4-1: 2014/04/29 HC-A(14) station moved downstream of 2013 due to bank failure at the cross section

A plot showing the creek flow at stations HC-A(03), HC-A(04), HC-A(06), HC-A(10), HC-A(11), HC-A(12) , HC-A(13) and HC-A(14) as well as precipitation data collected at the Road 32 Gauge, for the 2014 monitoring period is shown in Figure 4-11: 2014 Flow Monitoring for Hanlon Creek

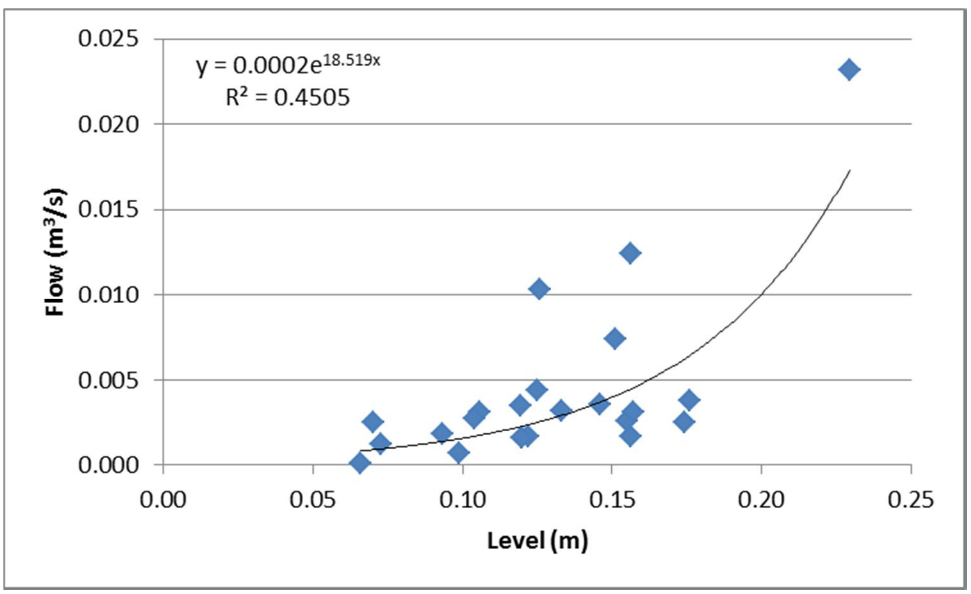

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Figure 4-2: Stage-Discharge Relationship used to Calculate Flow at Station HC-A(03) using 2012, 2013, and 2014 data

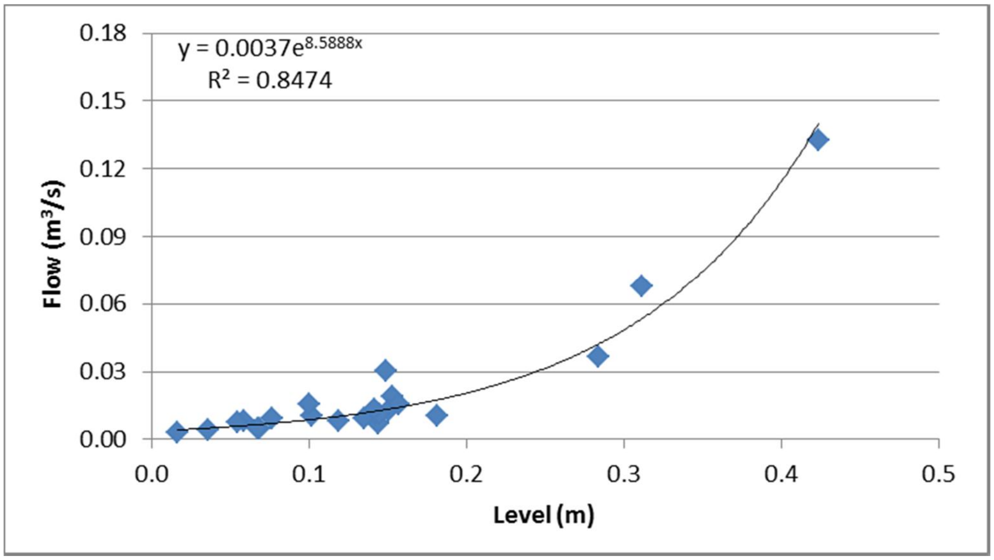

Figure 4-3: Stage-Discharge Relationship used to Calculate Flow at Station HC-A(04) using 2012, 2013, and 2014 data

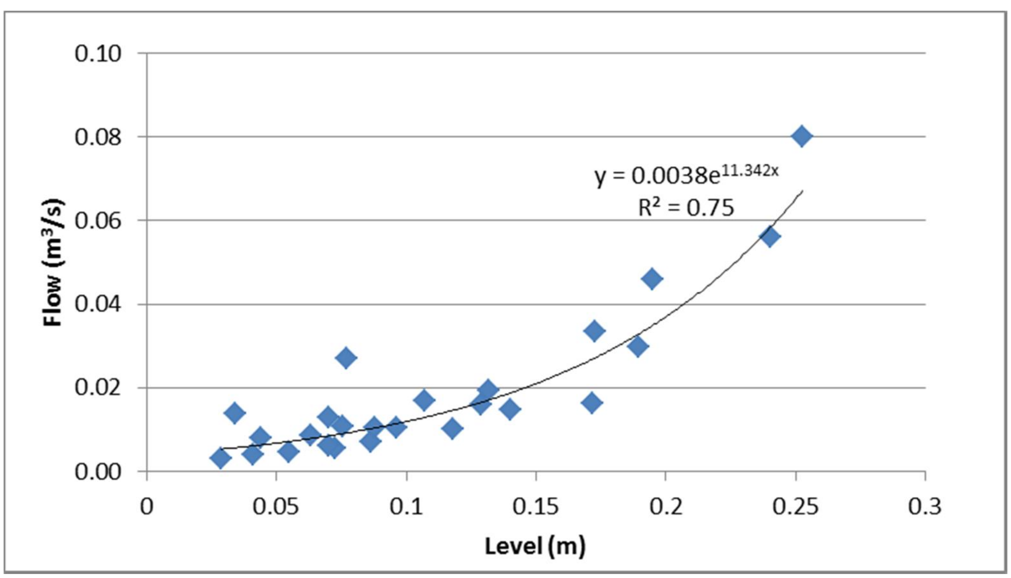

Figure 4-4: Stage-Discharge Relationship used to Calculate Flow at Station HC-A(06) using 2012, 2013 and 2014 data

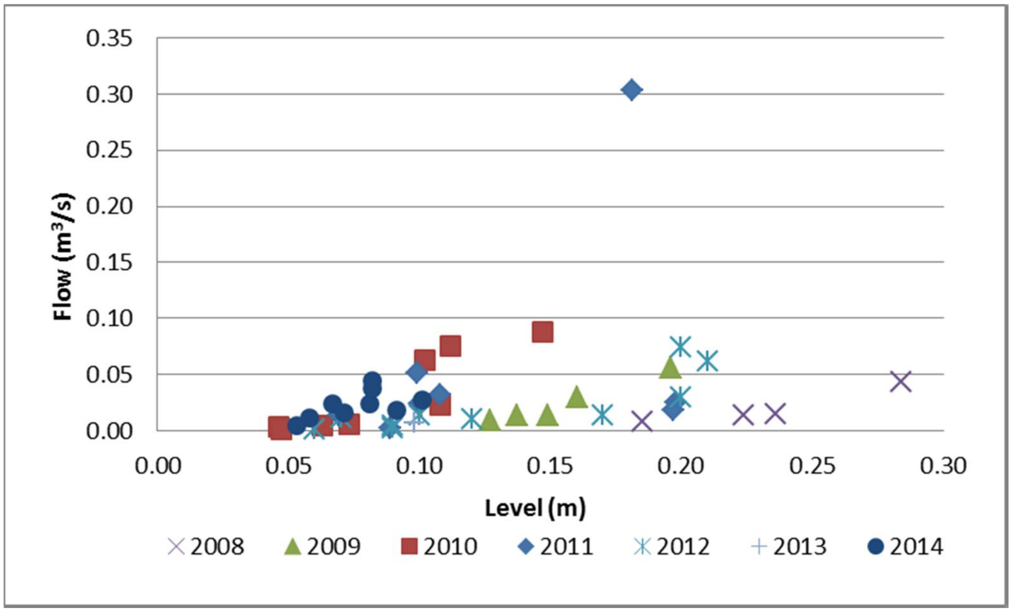

Figure 4-5: Stage discharge values from 2008 to 2014 at Station HC-A(10).

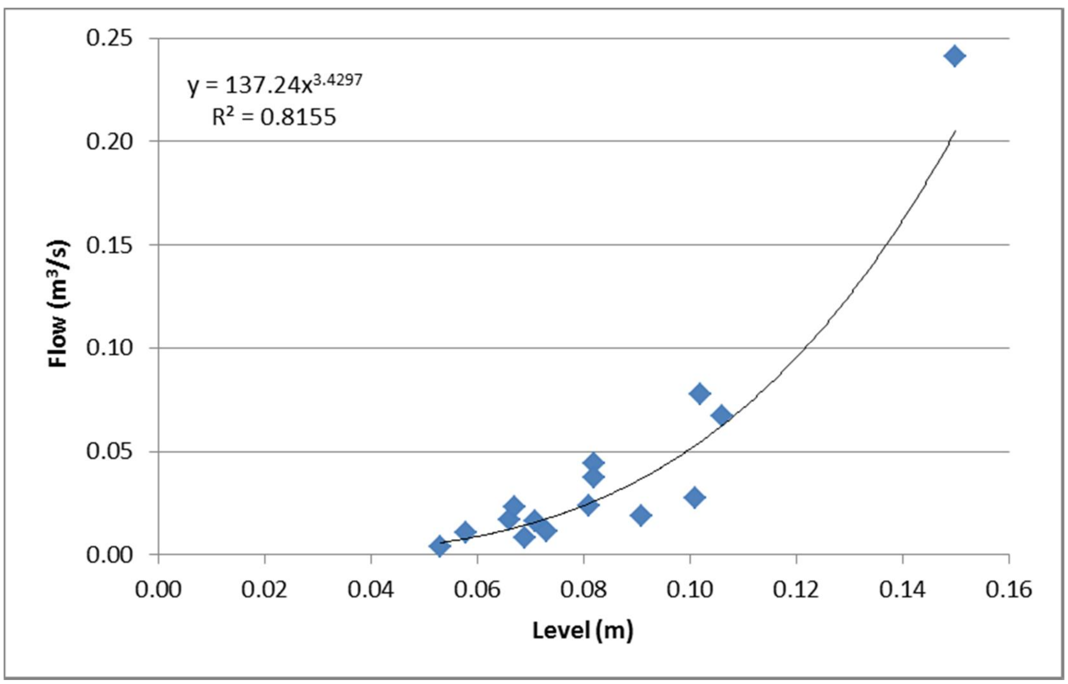

Figure 4-6: Stage-Discharge Relationship used to Calculate Flow at Station HC-A(10) for 2013 and 2014 data

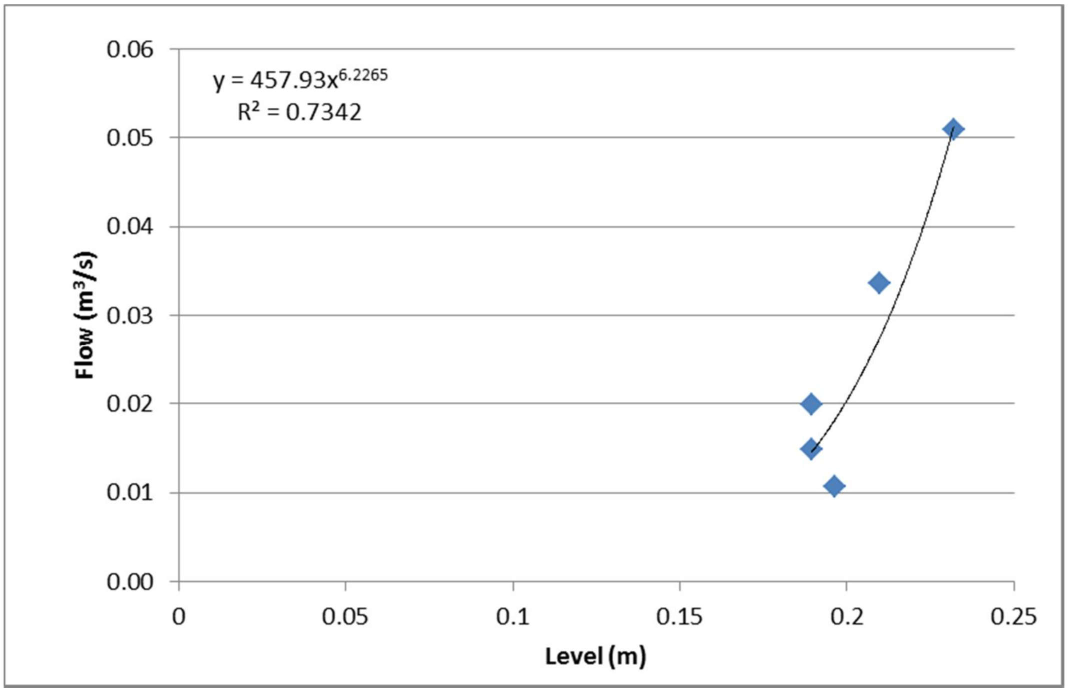

Figure 4-7: Stage-Discharge Relationship used to Calculate Flow at Station HC-A(11) for 2014

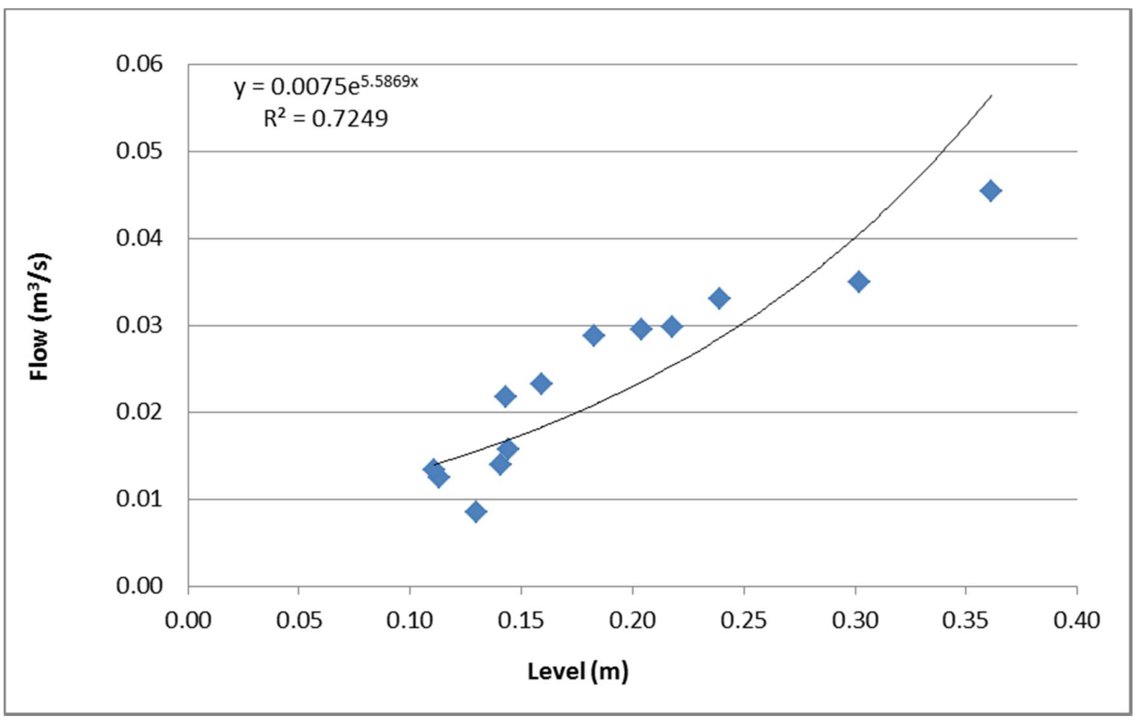

Figure 4-8: Stage-Discharge Relationship used to Calculate Flow at Station HC-A(12) for 2013 and 2014 data

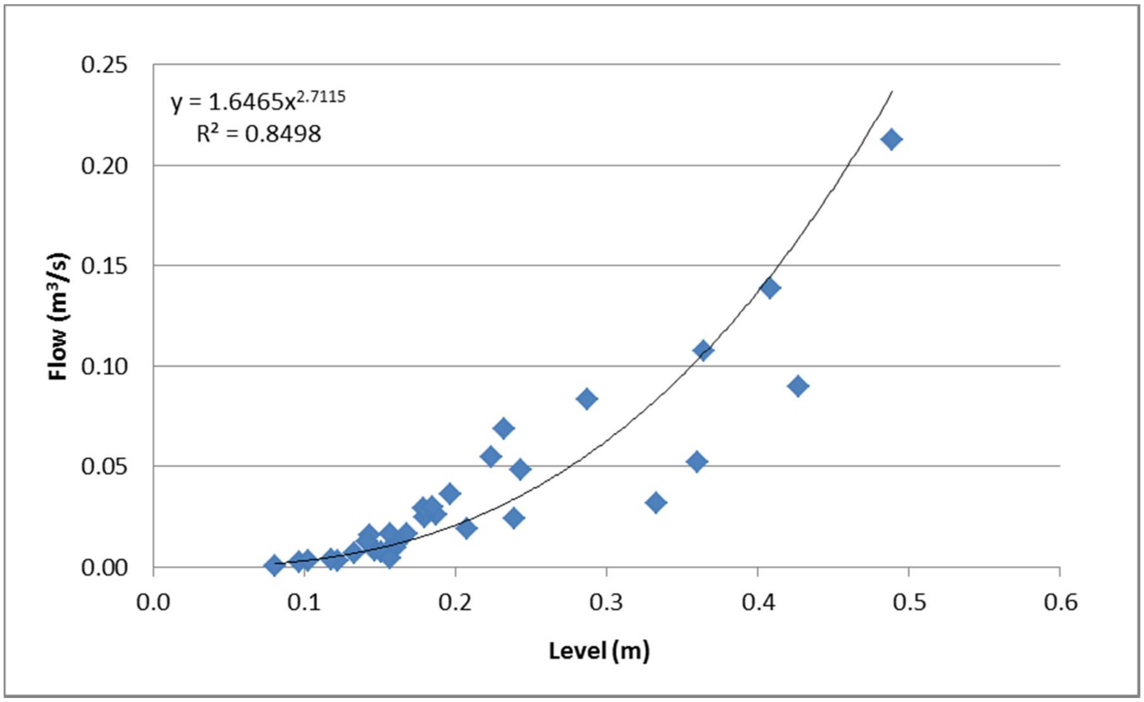

Figure 4-9: Stage-Discharge Relationship used to Calculate Flow at Station HC-A(13) for 2011 to 2014 data

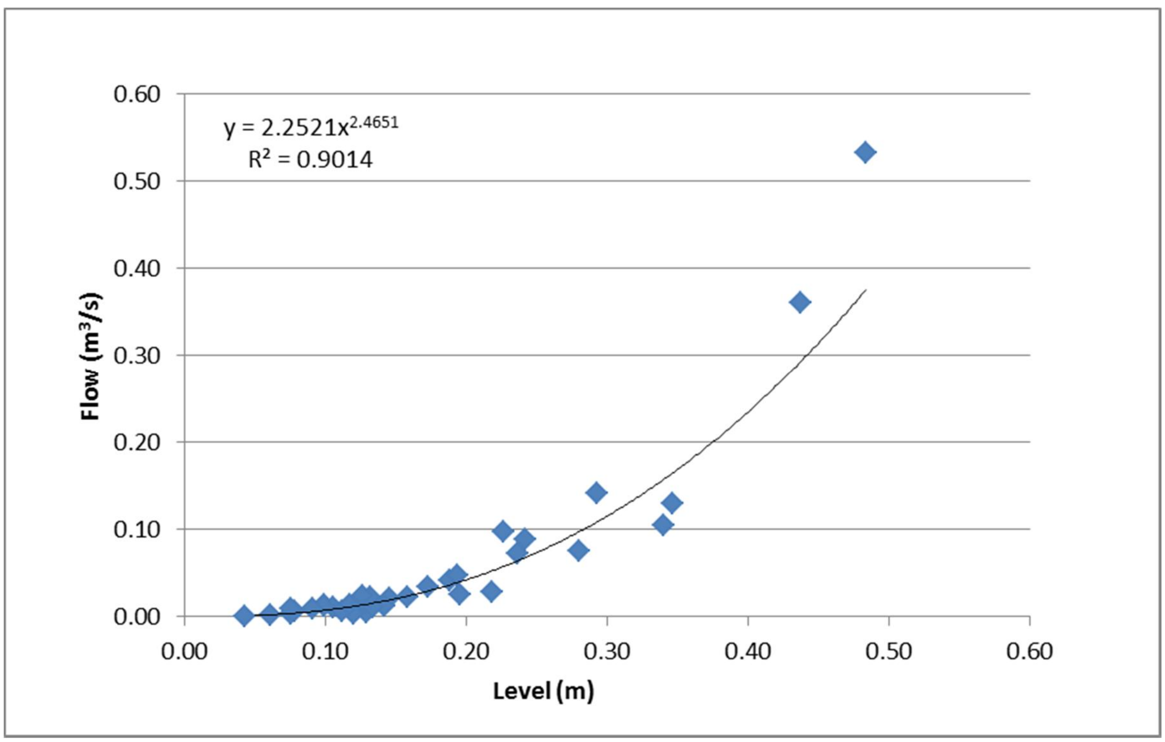

Figure 4-10: Stage-Discharge Relationship used to Calculate Flow at Station HC-A(14) for 2011 to 2014 data

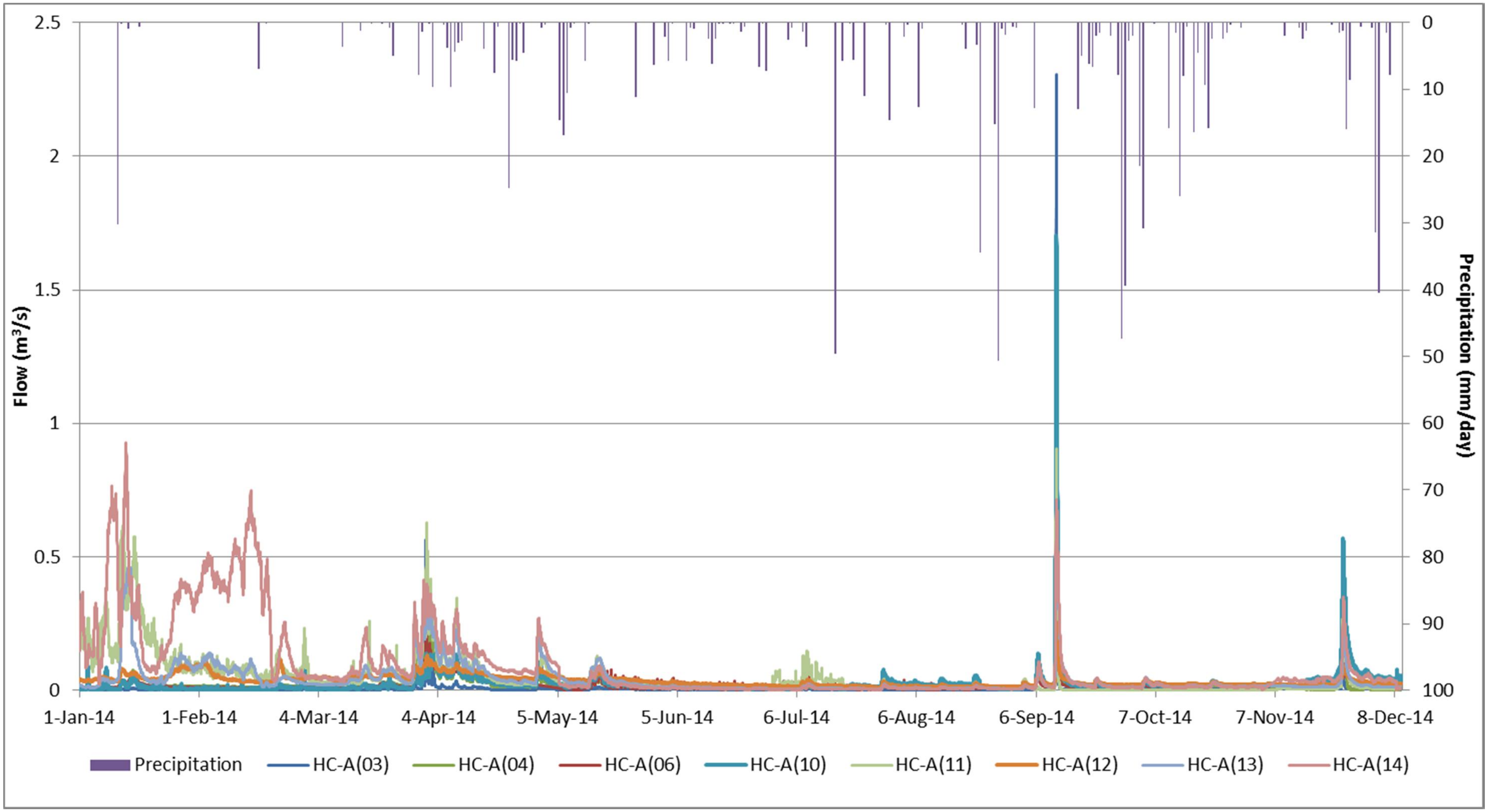

Figure 4-11: 2014 Flow Monitoring for Hanlon Creek

In addition to the continuous flow monitoring, baseflow measurements for each station HC-A(03), HC-A(04), HC-A(06), HC-A(08), HC-A(10), HC-A(11), HC-A(12), HC-A(13) and HC-A(14) were taken on between April 29th and December 1st, 2014, using a Flow Tracker 6300 - Acoustic Doppler Velocity Meter. These results are presented in **Table I** and shown graphically in **Figure 4-12**. A comparison of 2008 -2014 baseflow measurements are shown in **Table J.**

In 2014, baseflows were not influenced by construction impacts such as dewatering activities, like 2011 baseflows were. The 2014 precipitation levels for January and February more than doubled those recorded in each of the past two years and surpassed the historic average by close to 7mm. Even with the high precipitation levels in January, overall precipitation levels for winter 2014 were considerably lower than average due to an extremely dry March. The spring of 2014 experienced above average rainfall with a high number of precipitation events occurring throughout April and June. Higher precipitation amounts for both the winter and spring months lead to a much healthier snowmelt and groundwater recharge period compared to 2012 and 2013. Precipitation levels were significantly above average in July with levels falling to below average in August with precipitation only being recorded in the very beginning and tail end of the month. The fall months recorded above average precipitation amounts, while the months of November and December experienced precipitation levels far below the average. Overall, 2014 experienced higher average precipitation levels than the previous year but because of a small number of months receiving very little precipitation, 2014 still recorded lower than average precipitation values compared to the Canadian Climate Normals found in Table H. Higher precipitation levels contributed to increased baseflow measurements as 7 out of the ten stations recorded greater baseflow averages than 2013. Only station HC-A(03) experienced average baseflows lower than those observed in 2013.

Recorded baseflow discharge from HC-A(10) was slightly higher than 2013 but was still below average compared to historical records. Although measures were taken to reduce the outflow from Pond 4 in 2013, pond discharge was still observed to be near continuous causing high baseflow levels at HC-A(04). Increased baseflow levels at station HC-A(04) transformed the reach between HC-A(04) and HC-A(06) into a losing reach in 2014. The reach between HC-A(09) and HC-A(10) receives input from a small groundwater-fed tributary in the cedar swamp which helped it remain a gaining reach. HC-A(10) and HC-A(11) have historically been groundwater discharge areas and this was the case for 2014. HC-A(12), HC-A(13) and HC-A(14) were all areas of ground water recharge or losing reaches in 2014.

Table H: Observed precipitation trends for 2013 compared to Canadian Climate Normals

	Units	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Canadian Climate Normals (1971-2000) Guelph Arboretum	mm	56.4	50.8	72.1	78.3	79.9	76	88.5	95.9	92.1	69.2	86.3	77.7	**923.3**
Observed Guelph Turf Grass Institute 2011	mm	20	23.8	89.6	92.8	147.4	100.4	26.8	51.2	71.4	93.4	84.6	59.2	**860.6**
Observed Guelph Turf Grass Institute 2012	mm	39.2	17.0	28.4	31.0	32.2	90.0	54.6	98.4	127.0	129.0	11.6	57.8	**716.2**
Observed Guelph Turf Grass Institute 2013	mm	72.4	41.4	25.2	98.6	70.8	82.4	173.6	54.8	79.4	116.4	26.4	44.0	**885.8**
Observed Elora Research Station 2014	mm	51.2	58.1	46.7	101.7	54.1	68.8	133.7	51.1	27.9	74.3	63.3	45.8	**776.7**

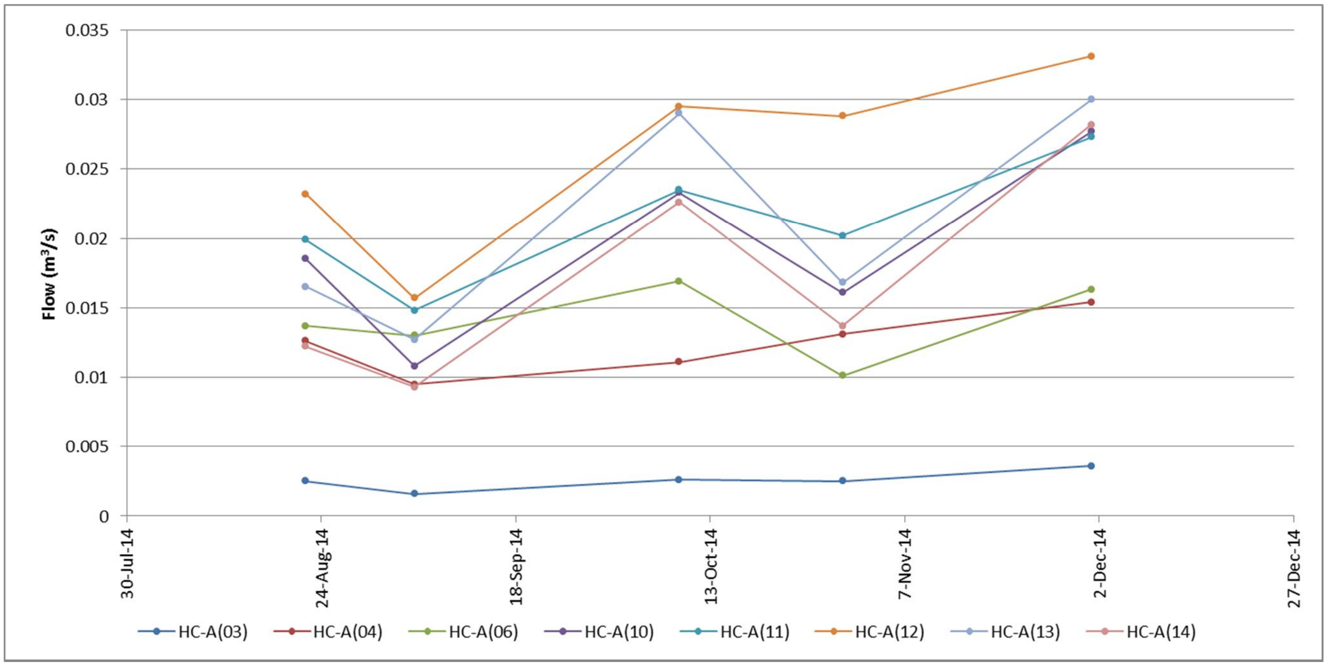

Figure 4-12: Hanlon Tributary A Baseflow Measurements – 2014

Table I: Hanlon Creek Baseflow Monitoring (m^3/s) – April 2014 to December 2014

Station	HC-A(03)	HC-A(04)	HC-A(06)	HC-A(10)	HC-A(11)	HC-A(12)	HC-A(13)	HC-A(14)
8/22/2014	0.0025	0.0126	0.0137	0.0185	0.0199	0.0232	0.0165	0.0122
9/5/2014	0.0016	0.0095	0.013	0.0108	0.0148	0.0157	0.0127	0.0093
10/9/2014	0.0026	0.0111	0.0169	0.0233	0.0235	0.0295	0.029	0.0226
10/30/2014	0.0025	0.0131	0.0101	0.0161	0.0202	0.0288	0.0168	0.0137
12/1/2014	0.0036	0.0154	0.0163	0.0277	0.0273	0.0331	0.03	0.0282

Table J: Hanlon Creek Baseflow Monitoring – 2008-2014 Summary (m^3/s)

Station	HC-A(03)	HC-A(04)	HC-A(06)	HC-A(08) Tributary	HC-A(09)	HC-A(10)	HC-A(11)	HC-A(12)	HC-A(13)	HC-A(14)
2008 Min	n/a	0.0035	0.0027	0.0021	0.0038	0.0077	n/a	n/a	n/a	0.0009
2009 Min	n/a	0.0039	0.0012	0.0030	0.0042	0.0050	n/a	n/a	n/a	0.0018
2010 Min	n/a	0.0004	0.0004	-0.0073	0.0011	0.0008	n/a	n/a	n/a	0.0009
2011 Min[2]	0.0028	0.0055	0.0008	0.0015	n/a	0.0024	0.0046	0.0050	0.0028	0.0015
2012 Min	0.0001[1]	0.0032	0.0031	0.0005	n/a	0.0013	0.0007	0.0017[1]	0.0006[1]	0.0007[1]
2013 Min	0.0012	0.0082	0.0055	n/a	n/a	0.0064	0.0027	0.0125	0.0034	0.0034
2008 Max	n/a	0.0113	0.0107	0.0100	0.0094	0.0168	n/a	n/a	n/a	0.0121
2009 Max	n/a	0.0149	0.0256	0.0221	0.0187	0.0563	n/a	n/a	n/a	0.0538
2010 Max	n/a	0.0029	0.0049	0.0123	0.0067	0.0222	n/a	n/a	n/a	0.0112
2011 Max[2]	0.0474	0.0566	0.0500	0.0059	n/a	0.0315	0.0460	0.0319	0.0482	0.0480
2012 Max	0.0025	0.0105	0.0146	0.0074	n/a	0.0132	0.0456	0.0176	0.0366	0.0207
2013 Max	0.0044	0.0168	0.0103	n/a	n/a	0.0169	0.016	0.0217	0.0158	0.0157
2008 Average	n/a	0.0060	0.0093	0.0090	0.0085	0.0205	n/a	n/a	n/a	0.0158
2009 Average	n/a	0.0078	0.0107	0.0093	0.0106	0.0213	n/a	n/a	n/a	0.0197
2010 Average	n/a	0.0016	0.0020	0.0024	0.0036	0.0071	n/a	n/a	n/a	0.0050
2011 Average[2]	0.0146	0.0217	0.0202	0.0027	n/a	0.0193	0.0206	0.0180	0.0205	0.0172
2012 Average	0.0011	0.0061	0.0075	0.0031	n/a	0.0080	0.0144	0.0106	0.0109	0.0091
2013 Average	0.0027	0.0112	0.0079	n/a	n/a	0.0104	0.0104	0.0161	0.0080	0.0099
2014 Average	0.0026	0.0123	0.0140	n/a	n/a	0.0193	0.0211	0.0261	0.0210	0.0172
Notes	[1] Hanlon Creek was noted to be dry or flows were below the measurement threshold flow at stations HC-A(03),HC-A(12), HC-A(13) and HC-A(14) [2] Baseflows were influenced by construction activities									

5. In-stream Water Quality Data

During each field visit a YSI multi-parameter probe (556R) was used to collect dissolved oxygen, pH, and specific conductivity conditions at each site. These results are shown graphically in **Figure 5-1** to **Figure 5-3**. The majority of the sites were within the ranges of the Provincial Water Quality Objectives (PWQO). In the event that water quality samples were collected and the pH probe was not functioning, then the pH was determined by the lab.

During some of the water base flow monitoring events, dissolved oxygen (DO) was below PWQO guidelines. This occurred once during the monitoring season at station HC-A (12). October 9th accounted for one event. Lower DO levels observed on this date could be attributed to below average flow rates due to high temperatures and an extended period of no precipitation. The number of days where pH levels were above PWQO guidelines was also recorded. This occurred one time each at HC-A (04) and HC-A (14) (1 event more basic than PWQO guidelines).

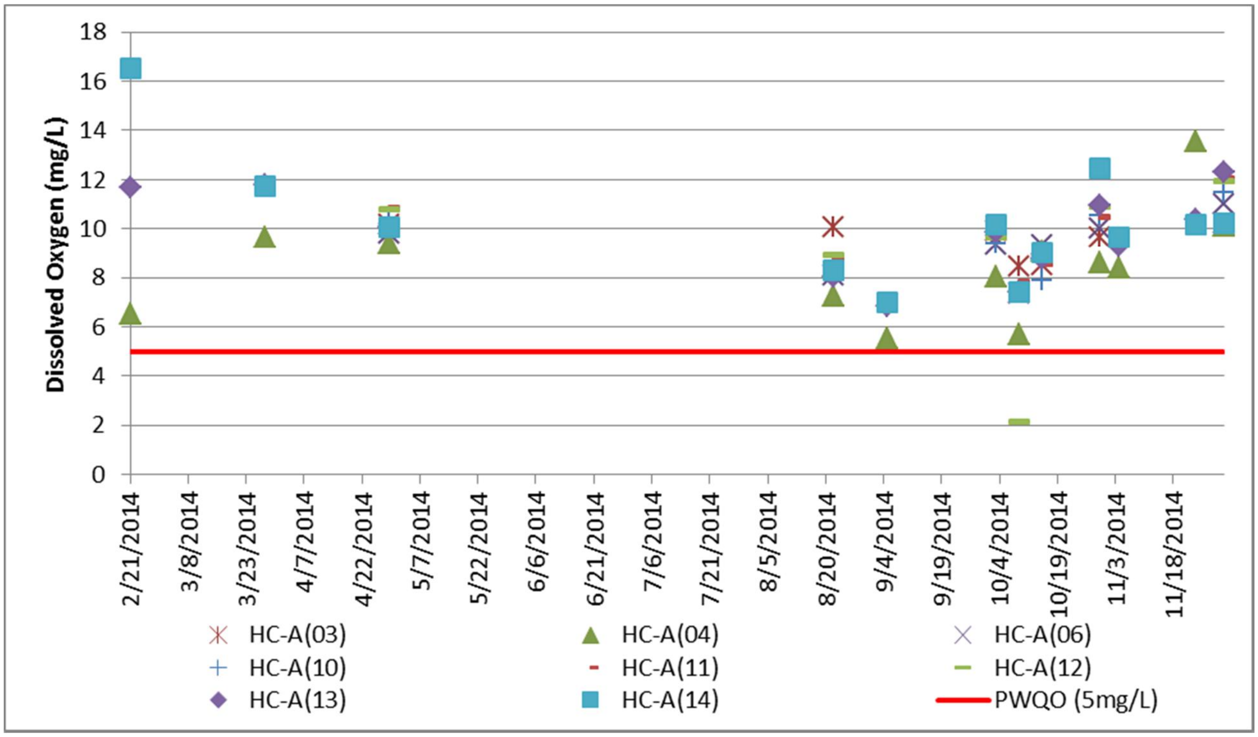

Figure 5-1: YSI Dissolved Oxygen Readings

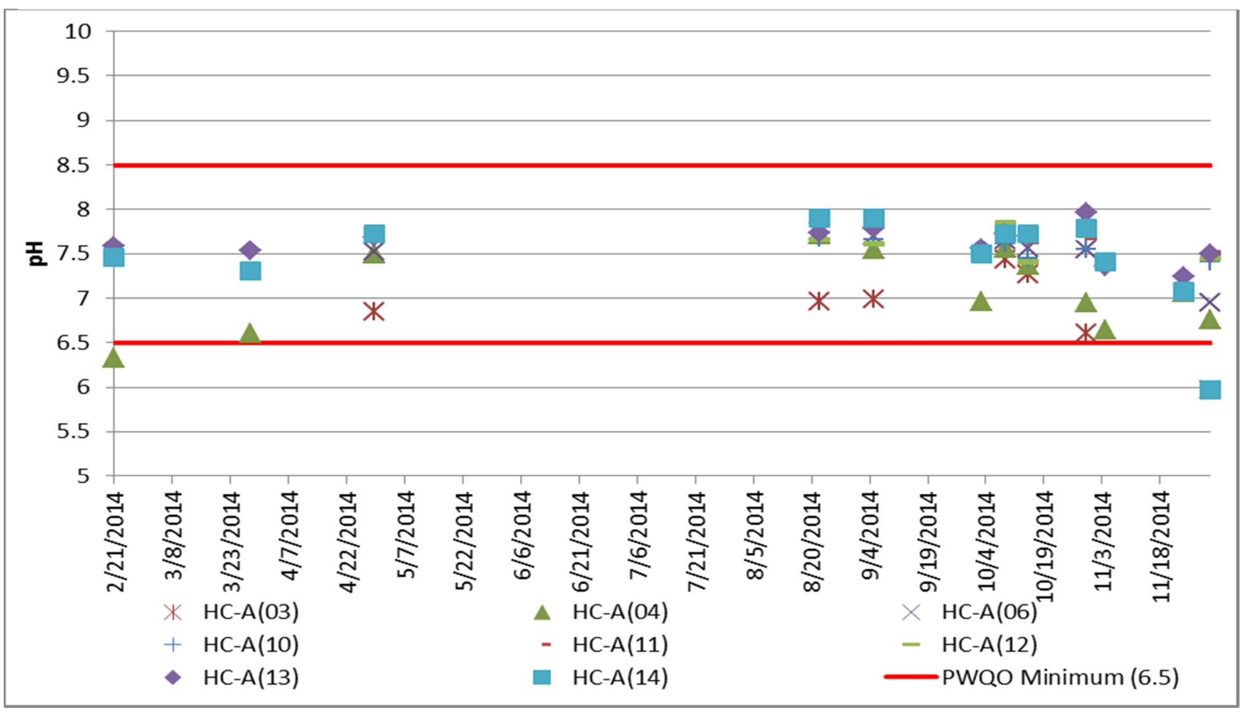

Figure 5-2: YSI pH Readings

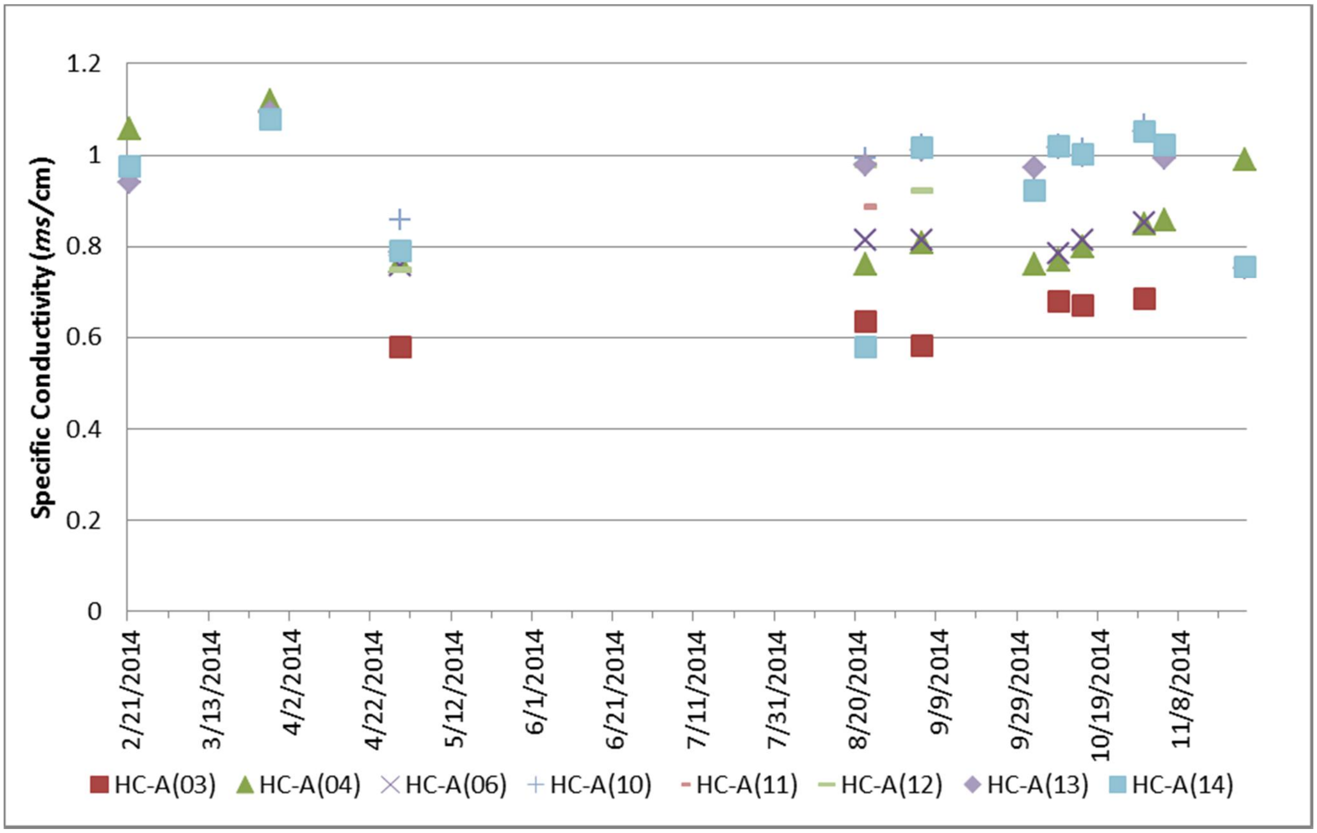

Figure 5-3: YSI Specific Conductivity Readings

In 2014, three turbidity monitoring stations were installed along Hanlon Creek at stations HC-A(03), HC-A(06), HC-A(11) and HC-A(14). A Turner Designs Cyclops turbidity sensor uses an optical scattered light method to determine turbidity. Data was collected over the 2014 year; however some issues were encountered with the turbidity data. It appears that loggers at HC-A(11) and HC-A(14) were buried under sediment for extended periods of time causing the sensor to record maximum turbidity levels. It is recommended that the depths be adjusted in 2015 to avoid sediment overcoming the sensors. There is also potential that biofouling and vegetation growth in the stream interfered with the sensor readings during 2014. **Figure 5-4** presents the turbidity monitoring results observed for the 2014 year.

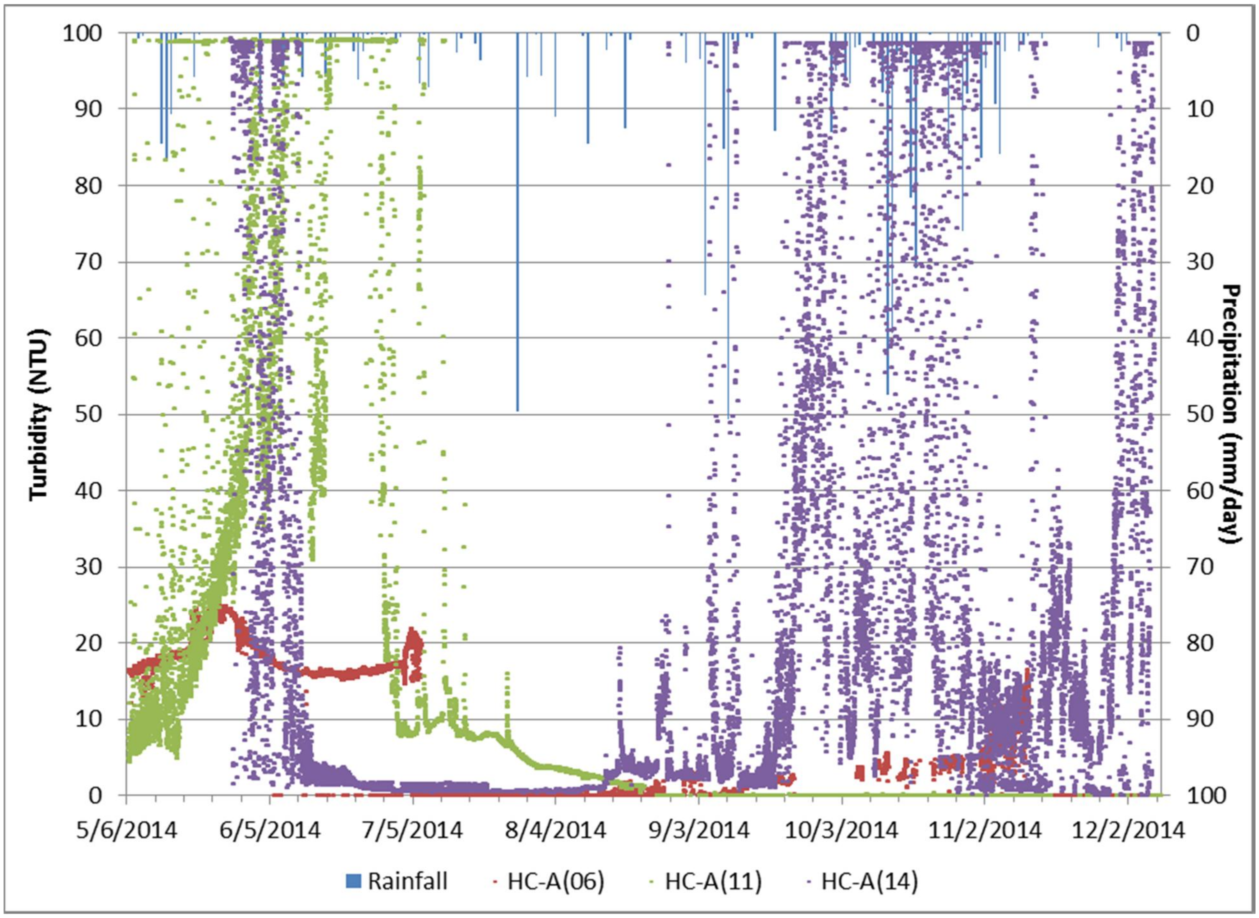

Figure 5-4: In stream Turbidity Measurements for 2014

6. Stormwater Management Facility Monitoring

As part of the Ministry of Environments CofA 1384-7QFPZQ and the Grand River Conservation Authorities (GRCA) requirements, monitoring was completed at each of the stormwater management (SWM) facilities. The monitoring included three components, water temperature, inflow and discharge flow rates, and water quality sampling. In 2014 monitoring was completed at Ponds 1, 2 and 4.

6.1 Flow

Inflows and outflows were computed based on water level loggers placed in each facility's inlet and outlet structures.

For Pond 1, flow was calculated for the two inlet structures (HC-P1(04) and HC-P1(05)) using the manning equations for flow through a partially full concrete pipe using typical n values of 0.013 for concrete. HC-P1(05) was set at an elevation such that it is impacted by tailwater conditions. This may overestimate the flow during dry periods. However, even during dry periods groundwater was typically entering the SWM pond at this location via the grassed swale. The logger at HC-P1 (06) was not installed after it went missing numerous times in early 2014. This cause large data gaps for 2014 monitoring season. Flow at the outlet structure was calculated as a flow through an orifice with the assumption that tail water levels would not be controlling water level elevation. Flows for Pond 1 are illustrated in **Figure 6-1**.

For Pond 2, flows were calculated for two of the three inlet structures (HC-P2(05) and HC-P2(06)) and the outlet structure (HC-P2(07)). Sufficient information was not available at HC-P2(04) to calculate the flow values, and the logger was influenced by tail water conditions for many of the wetter periods. Inflows were calculated at HC-P2(06) using the manning's equation for a grass lined trapezoidal swale. A Manning's n value of 0.04 was used for the swale as it is straight, but has vegetation growth. Due to an impediment to flow in the upstream channel, flow in this drainage swale only occurred during large storm events. Flows for Pond 2 are illustrated in **Figure 6-2**.

For Pond 4, flow was calculated for both the inlet structure (HC-P4(04)) and the outlet structure (HC-P4(05)). Inflows were calculated at HC-P4(04) using the manning's equation for a grass lined trapezoidal swale. A Manning's n value of 0.04 was used for the swale as it is straight, but has vegetation growth. The outflow from Pond 4 was calculated using the orifice equation based on the water level recorded by a level logger that was placed inside the outlet control structure (P4-(05)). Pond 4 continuously discharged water throughout the 2014 monitoring season. Flows for Pond 4 are illustrated in **Figure 6-3**.

With wetter conditions experienced in 2014, a greater amount of flow was observed exiting Pond 1 over the course of the year compared to previous years. These results show scattered discharge events occurring during the spring and summer seasons. Pond 2 was only found to be discharging for a small period of time midway through spring. After this only dry conditions were recorded at the pond's outflow.

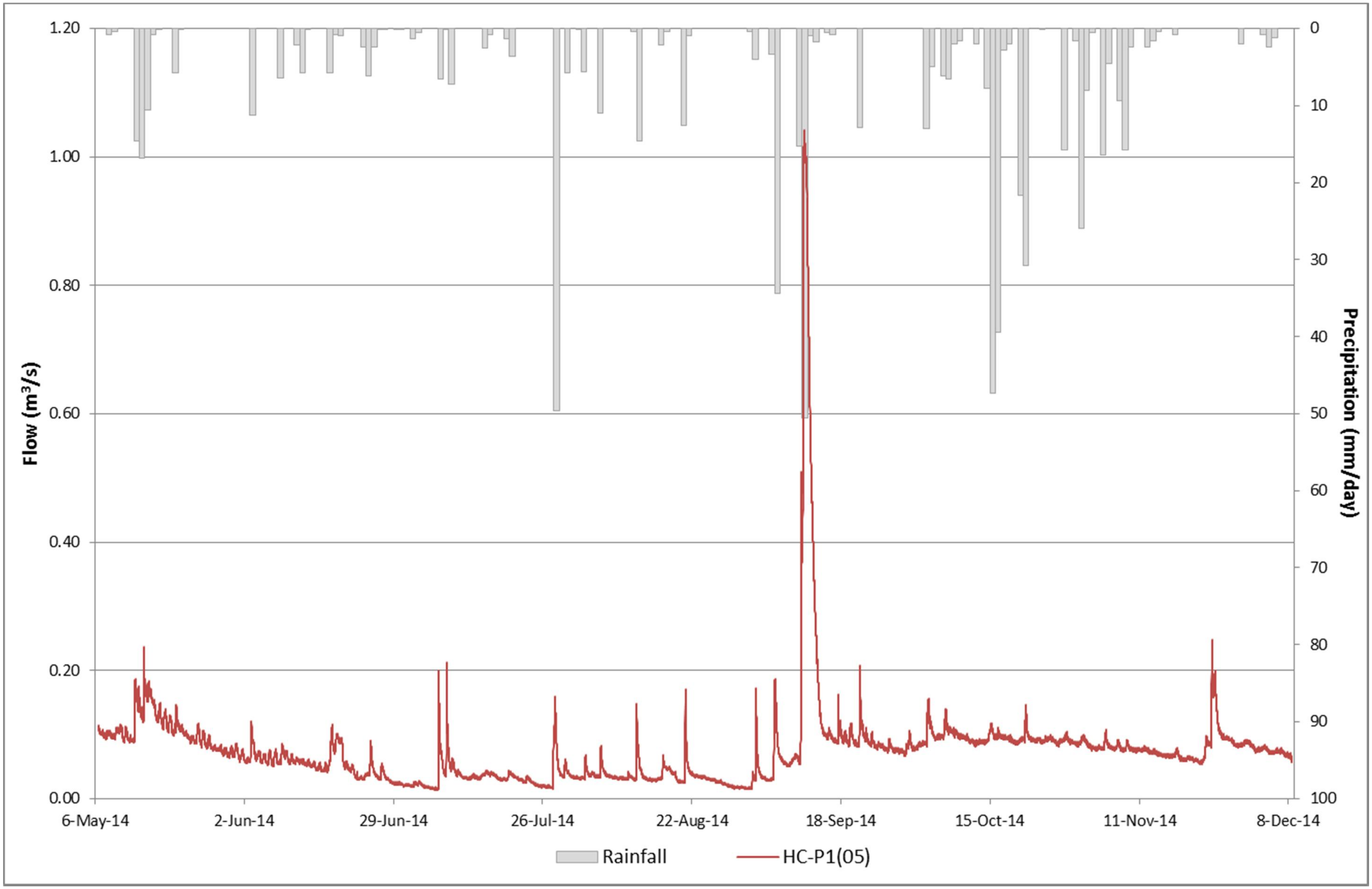

Figure 6-1: Measured Flow for Pond 1

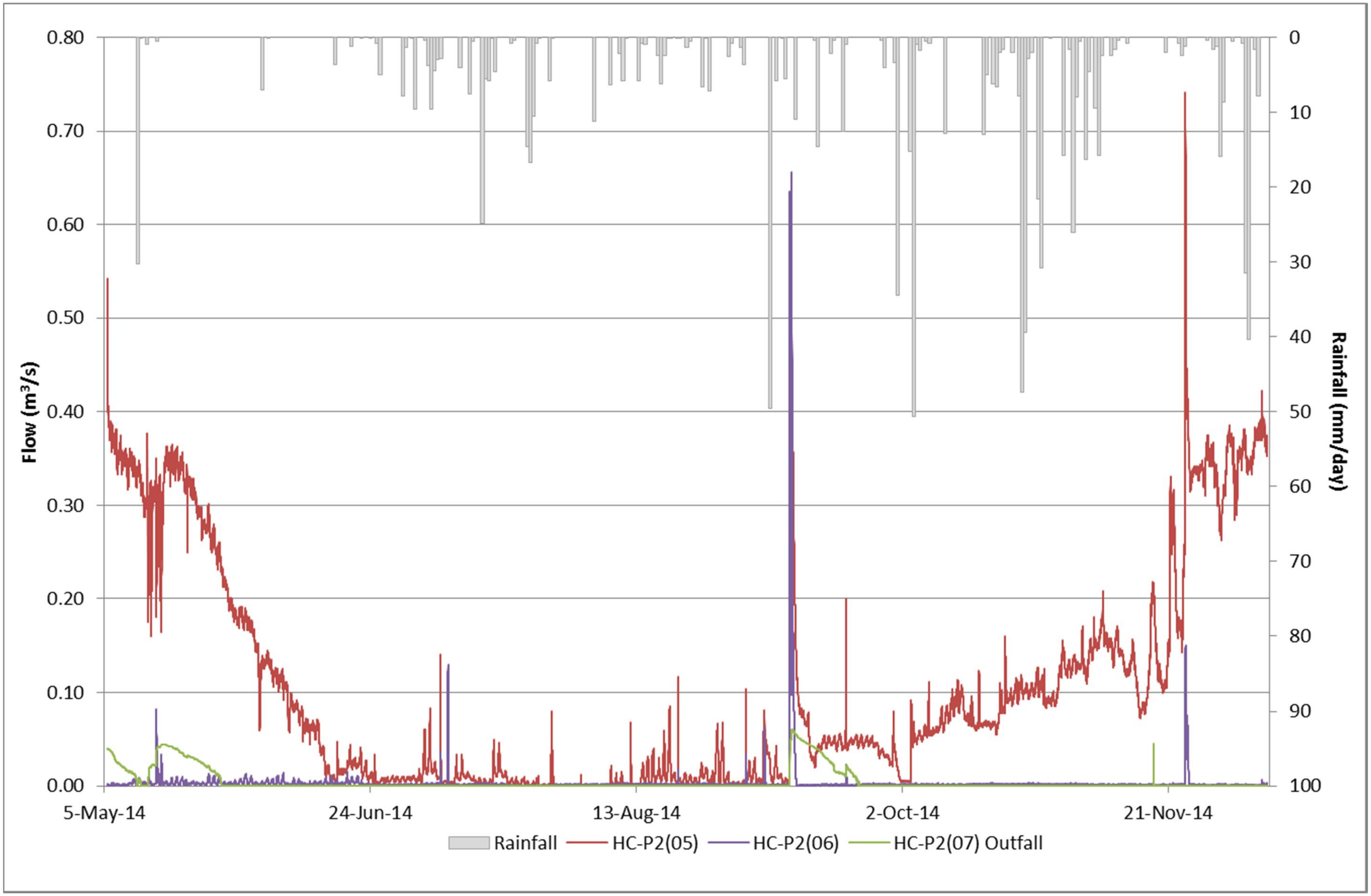

Figure 6-2: Measured flow for Pond 2

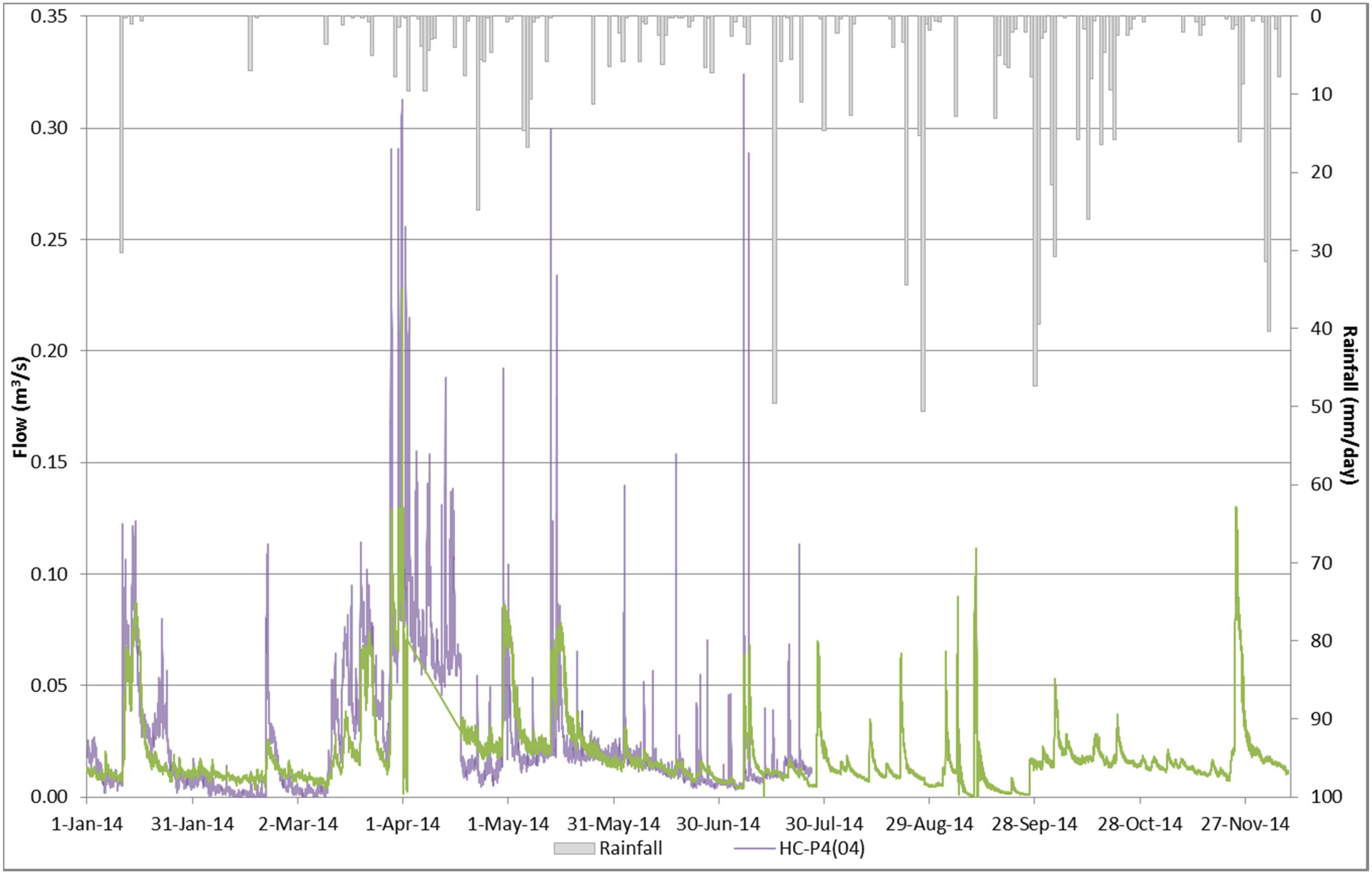

Figure 6-3: Measured flow for Pond 4

6.2 Temperature

Water temperature was monitored at the following locations at each of the SWM facilities:

- Inflow temperature;
- Outflow temperature; and
- Pond stratification temperate monitoring clusters.

The purpose of monitoring temperature in the SWM facilities is to illustrate that the mitigation measures that were incorporated into Hanlon Creek Tributary A are effective and that the water being discharged to the creek will not contribute to the warming of the steam.

6.2.1 Pond 1

Pond 1 was designed will the mutiple mitigation features. The stormwater is first conveyed to the SWM facility via two grass drainage swales and then discharged into the settling forbays. Before the water can pass though to the main body of the pond, the flow must pass though a planted wetland area. The water is discharged via a bottom draw structure and discharged into one of two cooling trenches prior to being discharged into the wetland areas. These measures allow for the maximum infiltratration, and minimize the amount of water directly discharged to the creek. Water temperatures were monitored in the inlet channels (HC-P1(04,05)), at the pond outflow structure (HC-P1(06)) and at the cooling trench outflows (HC-P1(07,08)). The thermal profile in the pond was also measured (HC-P1(01), HC-P1(02), HC-P1(03) - in order of deepest to shallowest placement - with HC-P1(03) very near the surface). A sample of the summer temperature variations and the complete temperature monitoring records at Pond 1 for 2013 is shown in Figure 6-4 and 6-5. Several large data gaps occurred during the monitoring year for Pond 1. HC-P1(04), HC-P1(07) and HC-P1(08) all experienced data loss (refer to **Table C**). There is no monitoring data for HC-P1(06) for 2014 because the logger was stolen multiple times and was not replaced for 2014. The temperature monitoring during a Pond 1 discharge event is also shown in **Figure 6-5** in order to more clearly illustrate the general pattern of the thermal regime throughout the pond. Temperature data for the closest upstream reach (HC-A(12)) and the next two downstream reaches (HC-A(13,14)) is also included in the analysis.

The HC-P1(03) temperature record demonstrated the greatest degree of fluctuation in measured water temperatures. This is due to its location near the surface of the water where temperature would be expected to change more rapidly in response to air temperature fluctuations. The logger located closer to the bottom generally recorded lower temperatures than the surface during the summer. During the storm event shown in **Figure 6-5**, the temperature variation through the water column (i.e. temperature difference between loggers P4(02-03)) collapsed as the water mixed; the distinct temperature stratification pattern reappeared within the days following the storm. During the winter, the surface of the pond froze or was near-freezing and temperatures were recorded as 0^{o}C, while below the surface, the water did not freeze and was generally near 4^{o}C

The loggers in the inlet channels (HC-P1(04,05)) were often exposed to solar heating and air temperatures due to low water levels in the channels. This resulted in temperature records with extreme daily fluctuations. Since these records do not accurately represent water temperature, they were excluded from Figures 6-4 and 6-5.

Pond 1 experienced little discharge throughout the summer so the majority of the cooling trench temperature data is not representative of actual discharge events. However, when a discharge event occurred, HC-P1(07) proved to be more effective at lowering water temperatures than HC-P1(08). Initially a cooling effect was observed at HC-P1 (08), however, as the event continued the temperature of HC-P1(08) matched and sometimes exceeded the temperature recorded at the HC-P1(06) outfall. The area covered by HC-P1 (08) is more open than the HC-P1(07) location leaving it more susceptible to solar heating and high temperatures. It does not appear that the cooling trench HC-P1 (08) is an effective means of lowering discharge temperatures.

6.2.2 Pond 2

The design of Pond 2 was a retrofit of an existing SWM facility. There are three inlets to the SWM facitly, two piped and one grass drainage swale. Each inlet discharges into its own sediment forbay. Before the water can pass through to the main body of the pond, the flow must pass though a planted wetland area, and then into the main body of the pond. The water is discharged via a bottom draw structure and into an infiltration gallery, that was constructed as part of the pond design for the existing SWM facility. These measures allow for the maximum infiltratration, and minimize the amount of water directly discharged to the creek.

6.2.3 Pond 4

Pond 4 was designed with mutiple mitigation features. The stormwater is first conveyed to the SWM facility via a grass drainage swale and then discharged into the settling forbay. Before the water can pass though to the main body of the pond, the flow must pass though a wetland area. The water is discharged via a bottom draw structure into a cooling trench prior to being discharged into Hanlon Creek Tributary A. Water temperatures were monitored in the inlet channel (HC-P4(04)), at the pond outflow structure (HC-P4(05)) and at the cooling trench outflow (HC-P4(06)). The thermal profile in the pond was also measured (HC-P4(01), HC-P4(02), HC-P4(03) - in order of deepest to shallowest placement - with HC-P4(03) very near the surface). The complete temperature monitoring records at the Pond 4 stations for 2014 are shown in
Figure 6-7. Data gaps occurred at all of the stations located in Pond 4. The temperature monitoring during a two week period in August is shown in **Figure 6-8** to more clearly illustrate the general pattern of the thermal regime throughout the pond between storm events. The temperature records from the creek stations upstream (HC-A(03)) and downstream (HC-A(04) and HC-A(06)) as well as precipitation and inflows are shown in **Figure 6-8**.

The logger in the inlet channel (HC-P4(04)) was often exposed to solar heating and air temperatures because the channel was dry, which resulted in a temperature record with extreme daily fluctuations. Since this record does not accurately represent water temperatures, it was excluded from Figures 6-7, 6-8 and 6-9.

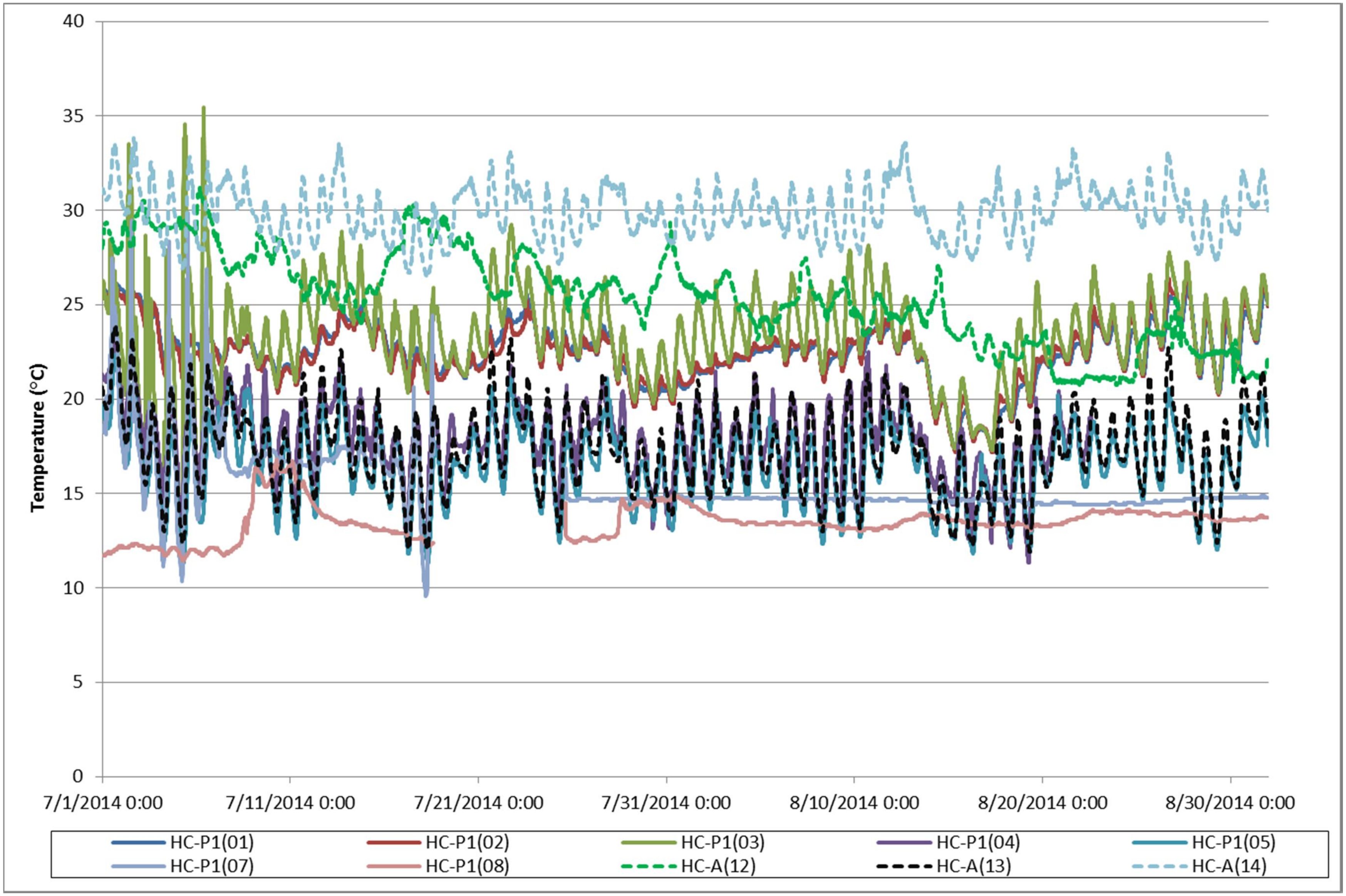

Figure 6-4: Measured summer temperatures through Pond 1

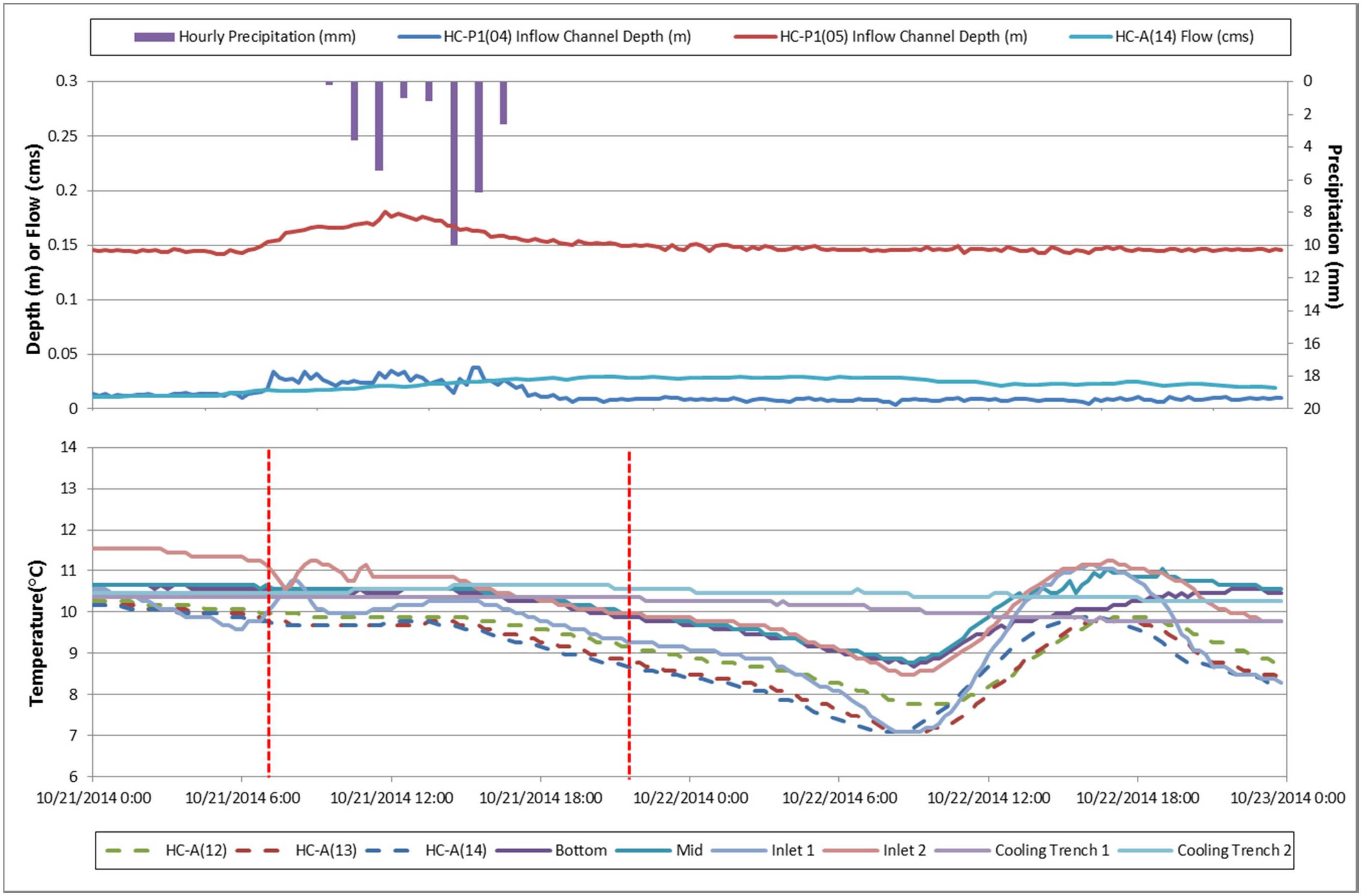

Figure 6-5: Pond 1: Computed outflow, measured inflow channel depth, and measured temperatures within and exiting pond; precipitation; measured temperatures on Tributary A (HC-A(12)) upstream and downstream (HC-A(13, 14)) of pond 1.

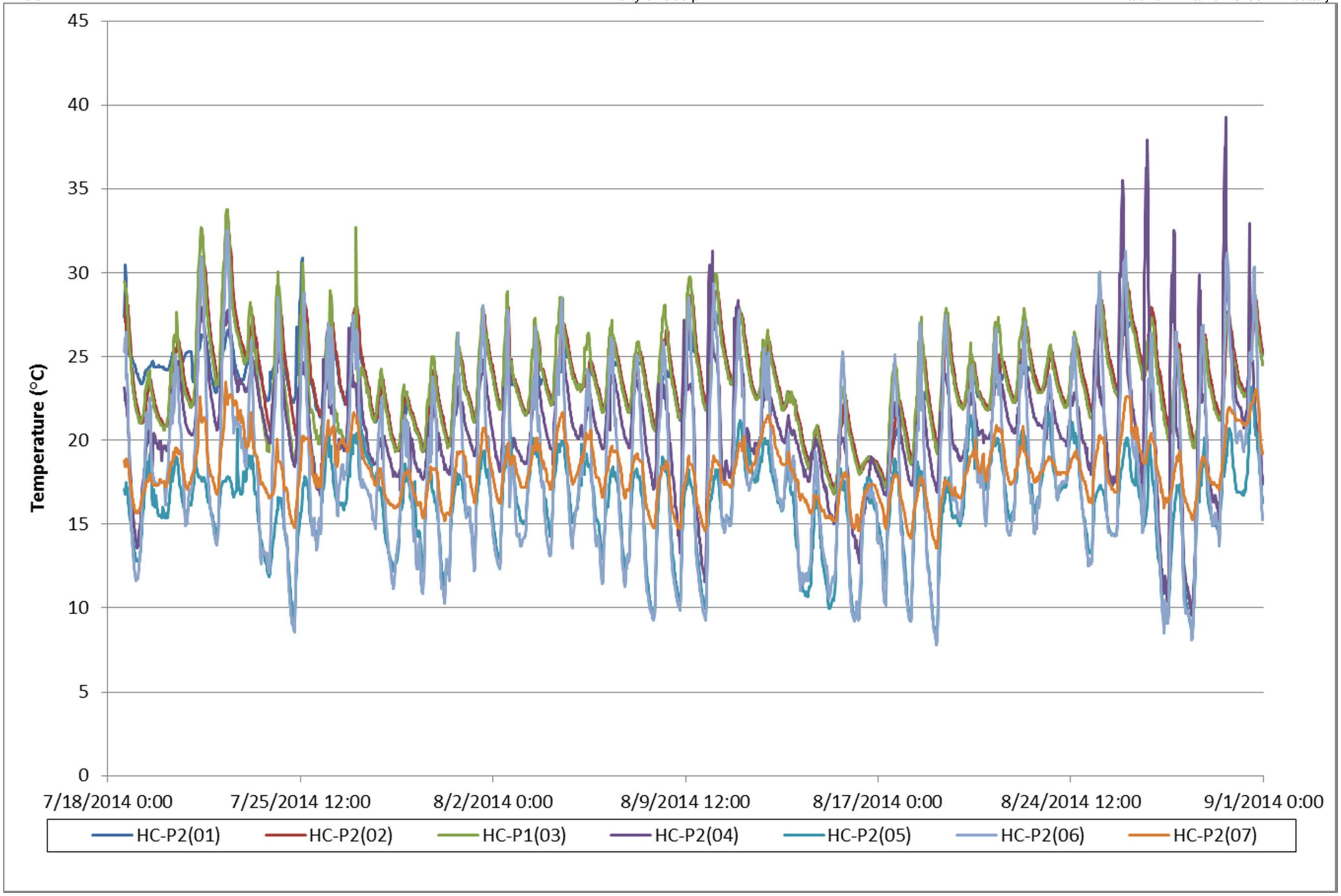

Figure 6-6: Measured temperatures through Pond 2

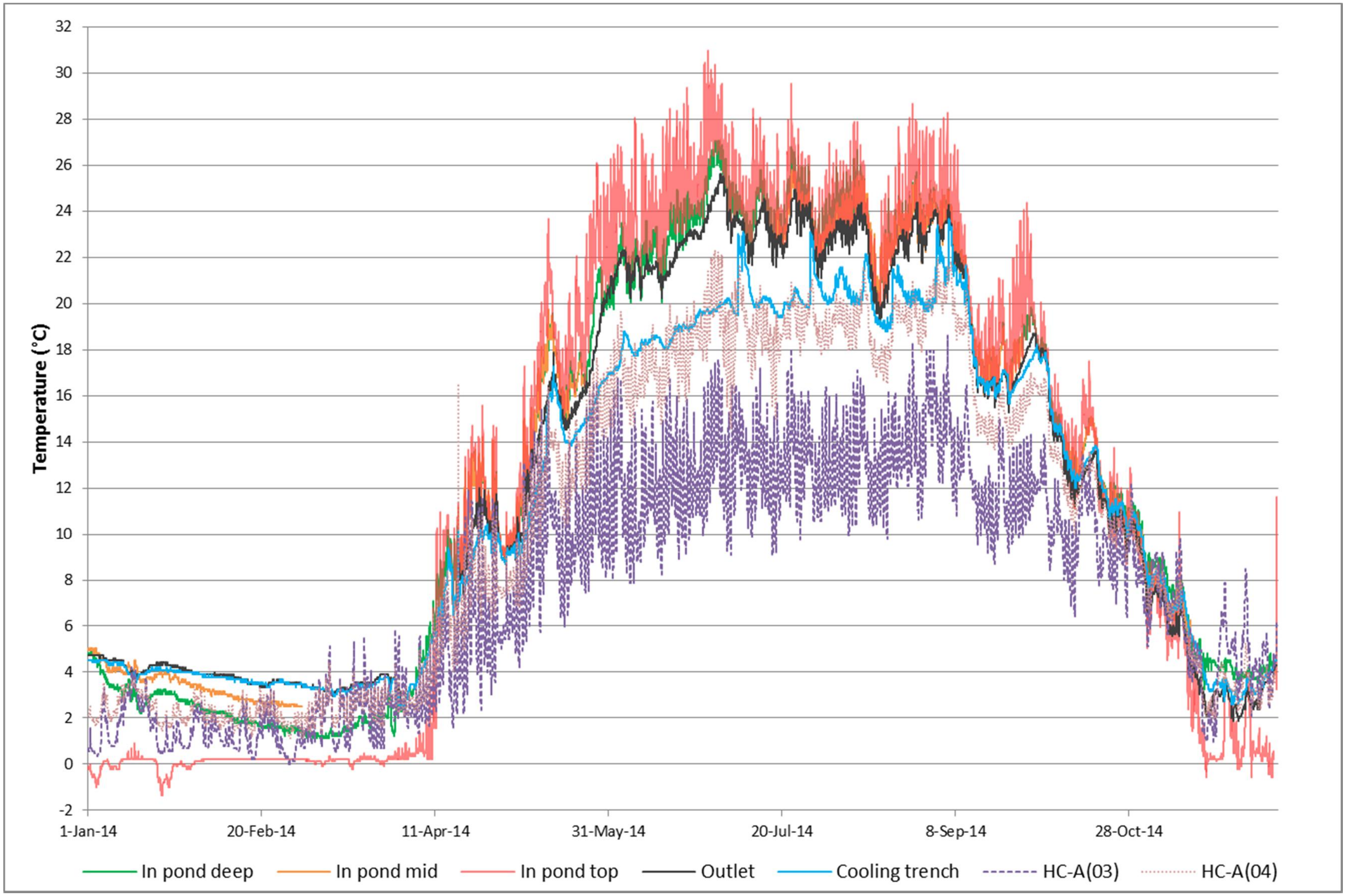

Figure 6-7: Measured temperatures through Pond 4

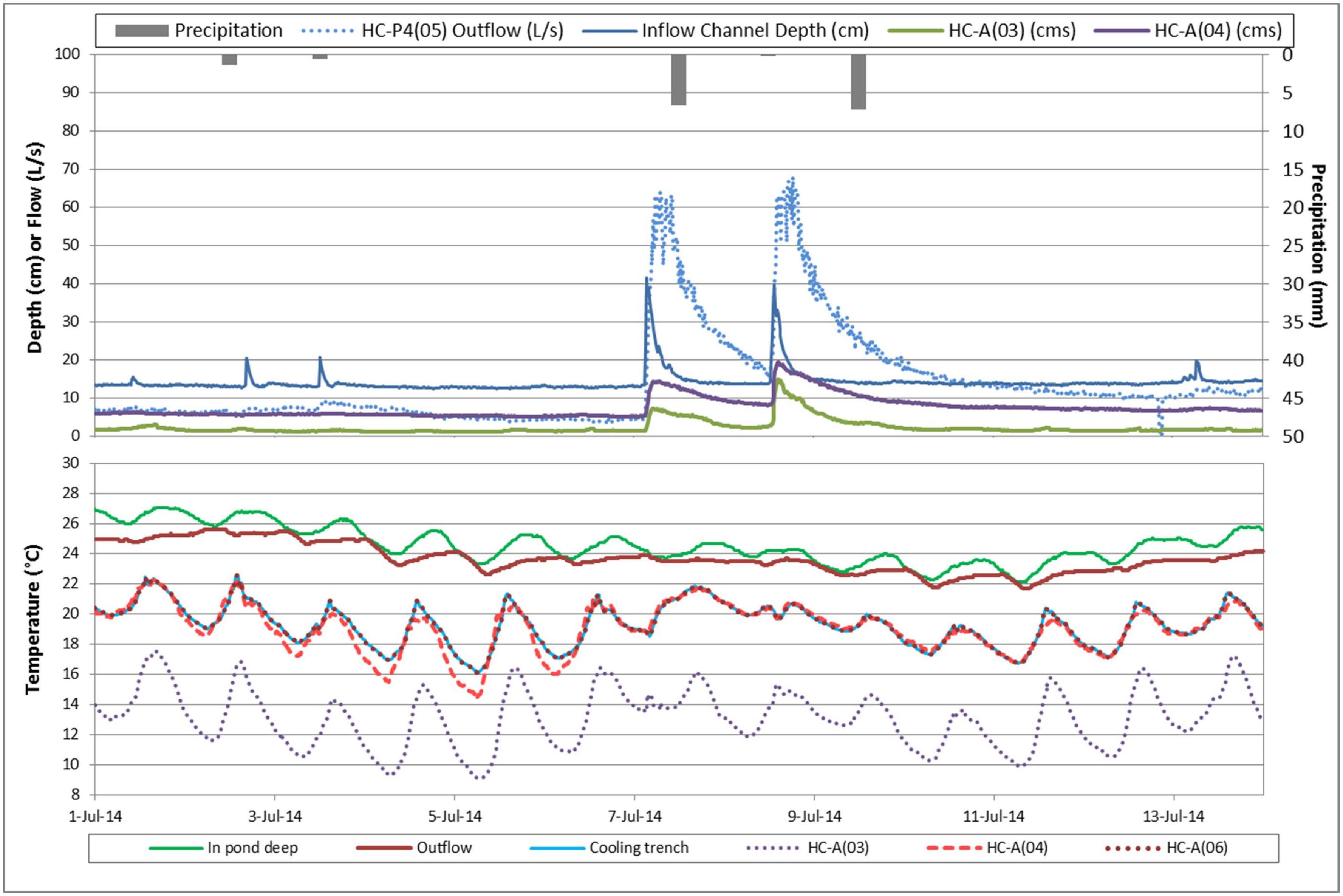

Figure 6-8: Pond 4: Computed outflow, measured inflow channel depth, and measured temperatures within and exiting pond; precipitation; measured temperatures on Tributary A (HC-A(03)) upstream and downstream (HC-A(04, 06)) of pond 4 during a wet period.

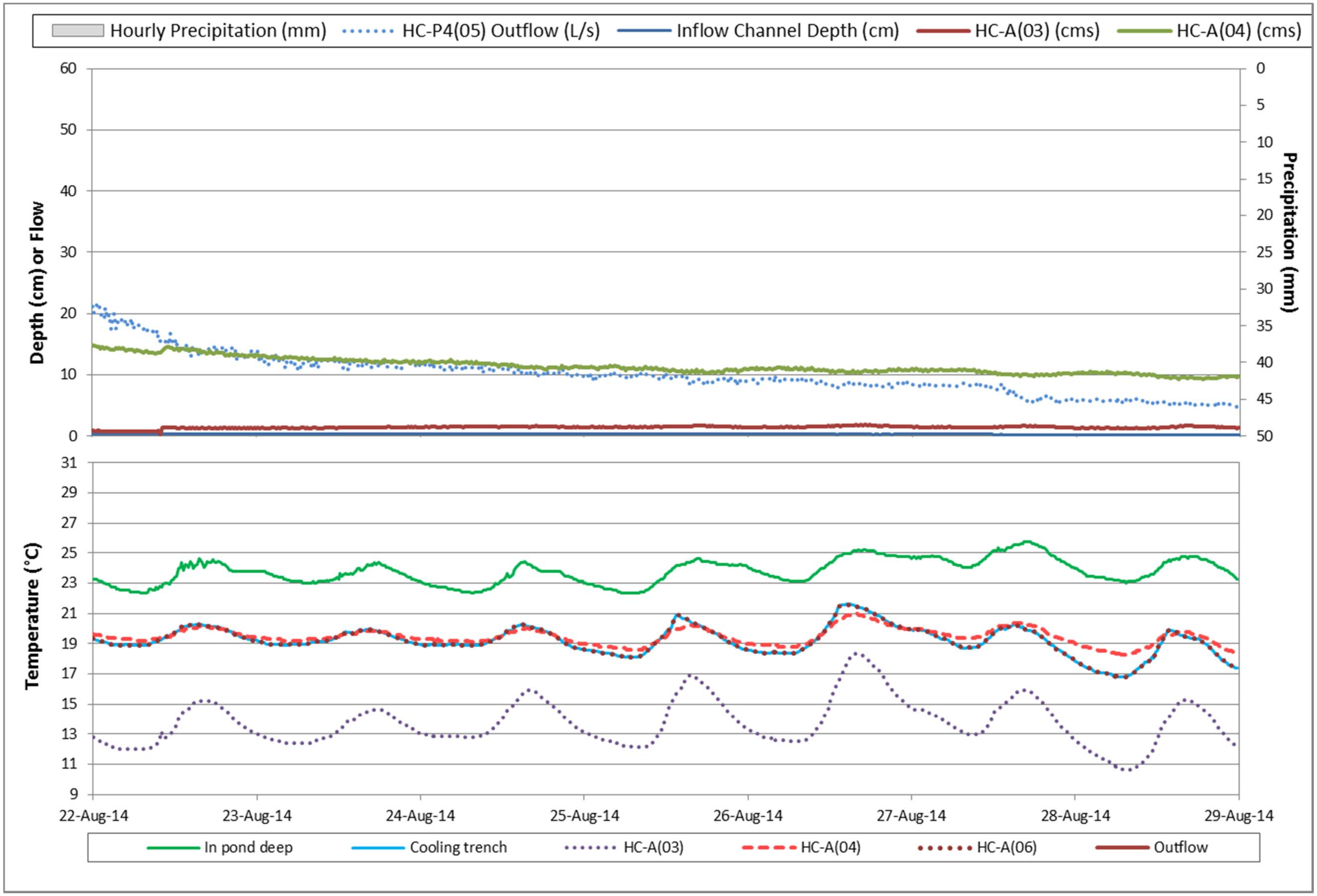

Figure 6-9: Pond 4: Computed outflow, measured inflow channel depth, and measured temperatures within and exiting pond; precipitation; measured temperatures on Tributary A (HC-A(03)) upstream and downstream (HC-A(04, 06)) of pond 4 during a dry period.

Similar temperature characteristics to Pond 1 were observed at Pond 4 over the course of the 2014 monitoring season. In addition, the temperature at the bottom-draw outlet (HC-P4(05)) was generally lower (during summer months) than the in-pond loggers (HC-P4(01-03)); it appears that the bottom draw outlet successfully allows for the discharge of the coldest (deepest) water first. The temperature recorded at the outlet of the cooling trench tended to have the least variation: it appears that the cooling trench did have a moderating, and generally cooling, effect on the flow discharged to Hanlon Creek Tributary A. Despite the cooling effects of the trench and bottom draw outlet, temperatures leaving the pond were still higher than water temperatures upstream from the outlet of Pond 4. The temperatures recorded at the creek station HC-A(04) downstream of Pond 4 were higher than those recorded upstream of the pond outlet (HC-A(03)) with several temperature threshold exceedances during the summer months (Table D). The moderating temperature effect of the cooling trench highlights the pond's temperature impacts on HC-A(04), which has a much smaller magnitude of diurnal temperature fluctuations than those observed in the creek sites upstream (HC-A(03)) and downstream (HC-A(06). At station HC-A(06), daily peak temperatures remain as high as those of HC-A(04), but atmospheric cooling at night exerts a greater impact on the daily minima observed at HC-A(06).

While the cooling design features at Pond 4 resulted in outflows that were often more than 5^{o}C less than the surface temperatures, the cooling trench outflows were still typically 3-6^{o}C warmer than the upstream station. In September 2012, vegetation was planted in the pond and the outlet weir was raised to reduce the constant discharge from Pond 4. Raising the weir height did not stop Pond 4 from continuously discharging in 2013. Additionally, plantings of vines and other fauna on the cooling trench were installed to shade the exposed rock. Although the plants did not mature to cover the cooling trench in 2013 and 2014, as seen in **Figure 6-10**, these additional design features are anticipated to provide additional cooling to the ponds discharge in future summer seasons.

Figure 6-10: Lack of vegetation growth on top of the Pond 4 cooling trench (7/28/2014)

6.3 Effluent Water Quality

To establish the performance efficiency of the SWM facilities and to satisfy the MOE Certificate of Approval, the water quality sampling program consists of grab samples at the inlet, outlet and downstream of each pond. Parameters that were analyzed in 2014 included:

- CBOD (5)
- Total Suspended Solids
- Total Phosphorus
- Dissolved Phosphorus
- Metals (total and dissolved, lead, zinc and copper)
- Escherichia coli
- Nitrate as N
- Chloride

The Consolidated Monitoring Program included the following water quality sampling requirements:

- One sample per season within one hour following the commencement of a storm event;
- One sample being for the snowmelt freshets;
- Five samples during summer months (June-September); and
- If flows permit, an additional sample should be taken 72 hours after precipitation.

Three wet samples and three dry samples were taken during the summer of 2014. The spring freshet sample and the winter sample were collected. Three of the 5 summer samples were collected and 3 fall sampling events were also collected. Flows did not permit for additional sampling 72 hours after a precipitation event. From April to October, Water levels at Pond 2 were too low prior to a rainfall event to result in stormwater being discharged from the outlet into Hanlon Creek Tributary A. Therefore, none of the 3 wet water quality samples was taken when Ponds 1 and 2 were discharging water. As a result, the only interactions between these SWM facilities and Hanlon Creek Tributary A would have occurred though ground water interactions. Samples collected during non-discharge periods in the summer months were taken directly from the SWM facilities. As such, the water samples did not necessary represent the water flowing into Hanlon Creek Tributary A. Pond 4 was discharging during the summer months and stormwater samples were collected from the pond outlet. The tabular results of the water quality sampling have been included in **Appendix E**.

Water quality sampling results are presented as a number of exceedances as compared to the Provincial Water Quality Objectives (PWQO) in **Table K**. A number of water quality parameters were typically higher in the SWM facilities with lower concentration in Hanlon Creek. E.Coli concentrations exceeded the recommended PWQO guidelines for recreational use for both wet weather and dry weather sampling events. Total phosphorus showed an overall reduction in phosphorus levels as the water moved though the pond. The instream phosphorus levels exceed the PWQO during both wet and dry weather sampling events. However; this is not uncommon for streams in the Grand River watershed (GRCA, 2012). Nitrate, total suspended solids, copper and lead all showed higher concentrations entering the SWM facilities with concentrations decreasing at the samples near the outlets. Aluminum, cadmium, copper, iron, lead, vanadium and zinc exceeded PWQO in the SWM facilities. However, instream levels did not exceed PWQO guidelines for aluminum or vanadium. Copper, iron, lead and zinc exceeded PWQO guidelines for both wet weather and dry weather sampling events. Zinc concentration in both the SWM facilities and instream exceeded PWQO.

In 2011, the Canadian Council of Ministers of the Environment (CCME) set standards for Chloride exposure indicating increased risk of harm to aquatic life after long term exposure to concentrations above 120 mg/L and short term exposure to concentrations above 640 mg/L(CCME 2011). Chloride concentrations were typically higher at pond outlets and in-stream locations, compared to samples taken at pond inlets. However, inlet chloride levels sharply increased during winter sampling. Short term exposure targets were exceeded at pond inlets HC-P1(04,05), HC-P2 (04,05) and HC-P4(05) during winter sampling events.

Table K: Number of Guideline Exceedances per Water Quality Sampling Location

			PWQO		CCME		Guelph Storm Sewer By-Law		Number of Exceedances for the Wet Weather Sampling Events											Number of Exceedances for the 3 Dry Weather Sampling Events			Total
Analyte	**Units**	**LOR[1]**	**Lower Limit**	**Upper Limit**	**Short Term**	**Long Term**	**Lower Limit**	**Upper Limit**	HC-P1 (04)	HC-P1 (05)	HC-P1 (06)	HC-P2 (04)	HC-P2 (05)	HC-P2 (06)	HC-P2 (07)	HC-P4 (05)	HC-A (04)	HC-A (13)	HC-A (14)	HC-A(04)	HC-A(13)	HC-A(14)	
Dissolved Oxygen(DO)	mg/L	0.05	5	-	-	-	-	-	6	4	5	1	3	2	2	8	6	6	8	3	9	9	72
pH	pH units	0.1	6.5	8.5	-	-	6	9	8	6	4	9	8	8	7	1	7	5	7	4	7	8	89
Chloride	mg/L	2	-	-	120	640	-	-	3	5	2	9	6	4	5	2	3	4	6	2	6	7	64
Total Phosphorus	mg/L	0.003	-	0.02	-	-	-	-	8	7	5	9	8	8	8	7	10	7	9	6	10	10	112
E. Coli	CFU/100mL	10	-	100	-	-	-	-	0	3	0	0	0	0	0	0	0	0	0	0	0	0	3
Aluminum (Al)-Total	mg/L	0.01	-	0.015	-	-	-	-	0	3	0	1	3	2	0	0	1	1	0	0	1	0	12
Arsenic (As) - Total	Mg/L	0.001	-	0.005	-	-	-	-	3	7	0	0	1	3	0	0	0	0	0	0	0	0	14
Cadmium (Cd)-Total	mg/L	0.00009	-	0.0001	-	-	-	0.001	8	5	3	0	8	8	8	3	9	5	5	5	7	6	80
Cobalt (Co)-Total	mg/L	0.0005	-	0.0009	-	-	-	-	5	5	0	8	6	3	5	0	5	2	2	3	3	2	49
Copper (Cu)-Total	mg/L	0.001	-	0.001	-	-	-	0.01	4	5	0	9	7	5	6	0	4	2	1	2	3	3	51
Iron (Fe)-Total	mg/L	0.05	-	0.3	-	-	-	-	2	3	0	0	1	1	0	0	0	0	0	0	0	0	7
Lead (Pb)-Total	mg/L	0.001	-	0.001	-	-	-	0.05	4	4	0	8	6	3	1	0	10	4	3	6	5	3	57
Vanadium (V)-Total	mg/L	0.001	-	0.006	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zinc (Zn)-Total	mg/L	0.003	-	0.02	-	-	-	0.05	2	0	0	5	3	5	6	0	0	0	0	0	0	0	21
Zirconium (Zr)-Total	mg/L	0.004	-	0.004	-	-	-	-	7	3	2	9	6	6	6	1	1	0	0	0	0	0	41
Aluminum (Al)-Dissolved	mg/L	0.01	-	0.015	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Copper (Cu)-Dissolved	mg/L	0.001	-	0.001	-	-	-	-	0	0	1	1	2	0	0	0	7	0	0	4	0	0	15
Silver (Ag)-Dissolved	mg/L	0.0001	-	0.0001	-	-	-	-	6	4	5	1	3	2	2	8	6	6	8	3	9	9	72
Zinc (Zn)-Dissolved	mg/L	0.003	-	0.02	-	-	-	-	8	6	4	9	8	8	7	1	7	5	7	4	7	8	89

Notes: [1] Limit of reporting (LOR)

HC-P1(04), HC-P2 (05), HC-P2 (06), HC-P2 (07), and HC-P4 (05) Were Sampled 8 times

HC-P1(05), HC-A (13) Were Sampled 7 times

HC-P1(06) and HC-A(04) were sampled 6 times

HC-P2 (04) and HC-A (14) were sampled 9 times

HC-A(04), HC-A(13) and HC-A(14) were sampled 10 times

7. Conclusions and Recommendations

Air temperatures during the summer of 2014 were generally cooler compared to previous years and Canadian Climate Normals. These monitored temperature results show that the system experienced cooler temperatures than in previous years, largely due to the cooler summer months and higher precipitation levels. However overall monitoring results show summer temperatures may still not have been suitable for brook trout habitat based on the ranges provided in the Hanlon Creek Business Park Stream Temperature Impact Report Continuous Modeling with HSP-F (AECOM, 2009). It is not expected that the Pond 2 SWM facility was the cause of the temperature exceedances observed during 2014, as there was no direct flow from these facilities during the summer months. Pond 1 experienced infrequent periods of low flow during the summer months and it is possible it contributed to exceedances observed at HC-A(13) and HC-A(14) due to an ineffective cooling trench. Pond 4 was continuously discharging into Hanlon Creek Tributary A during the summer of 2014 and is likely a contributing factor to the observed increased temperatures at stations downstream of the pond outflow. The bottom-draw and cooling trench design of pond 4 resulted in discharge that was cooler than water in the pond, but still higher than the creek monitoring station upstream of the creek. Vegetation that was planted on the banks of the pond and along its cooling trench in 2012 had not matured and therefore did not provide additional cooling benefits to Pond 4. It is expected that with the vegetation growth, water temperatures will decrease.

Improved baseflow patterns were observed in 2014 when compared to 2013. However, the observed patterns were still considered to be below average compared to baseflow averages prior to 2012. Although downstream reaches did not dry up, they experienced low baseflow levels. Increased precipitation levels combined with extended wet and dry periods throughout the summer aided, in combination with groundwater inputs, in generating the observed 2014 baseflow patterns.

The monitoring program should be continued during and post construction to verify the temperature trends that were observed during 2014. Monitoring should continue both within the stormwater ponds and the stream to identify the function of each mitigative element in the system (bottom draw, cooling trench, increased vegetative cover). Results of this program should be annually reported to ensure the recommended adaptive management approach is meeting the intended targets. Flow monitoring should also continue in future monitoring initiatives.

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HANLON CREEK BUSINESS PARK

CONSTRUCTION-PHASE AQUATIC MONITORING 2014

Prepared for:

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1.0 Introduction

The need for aquatic monitoring for the Hanlon Creek Business Park development was identified in the *Hanlon Creek Business Park Consolidated Environmental Impact Study* (NRSI 2004), which recommended benthic invertebrate sampling and more frequent fish sampling at the state-of-the-watershed fish sampling site. Monitoring of aquatic habitat was also recommended in the conditions for the Draft Plan approval of the Hanlon Creek Business Park as set by the Ontario Municipal Board (2006). Specifically, Draft Plan Condition #12 requires that thermal impact of stormwater management ponds be monitored.

A multi-disciplinary monitoring program was developed for the Hanlon Creek Business Park (HCBP) development to achieve a variety of objectives, including the aquatic habitat. The overall monitoring program also includes terrestrial features, hydrogeology, surface water flows, surface water temperatures, benthic invertebrates and fish.

This monitoring report addresses the benthic invertebrate and fish communities. The aquatic monitoring components were implemented prior to construction to establish an adequate baseline data set against which development conditions can be compared. The pre-construction data includes the years 2006 - 2009. Data has been collected at 5 stations (3 stations prior to 2009). One of the stations coincides with the aforementioned state-of-the-watershed fish sampling station. Monitoring will continue until 75% of the development is built by area in Phases I, II and III of the HCBP, plus an additional 2 years.

In 2014, construction activities continued within the Hanlon Creek Business Park. Construction activities began in 2010 with grading, servicing, and building construction initiated. As a result, aquatic monitoring conducted since 2010 is considered construction-phase monitoring.

In addition to the monitoring for the HCBP, state-of-the-watershed monitoring in the Hanlon Creek watershed is to occur on a 5-year schedule based on the recommendation for long-term monitoring in the Hanlon Creek Watershed Plan (1993). The aquatic component of the state-of-the-watershed monitoring includes one fish sampling site within the HCBP development lands. The Hanlon Creek State-of-the-Watershed Report (PEIL 2004) is a report on the state-of-the-watershed monitoring.

2.0 Study Area

Hanlon Creek Business Park is located in the south end of the City of Guelph. As shown on Map 1, the project area is bounded to the east by Hanlon Expressway, to the north by the Kortright IV subdivision, to the west by Downey Road and to the south by Forestell Road. Laird Road runs parallel to Forestell Road, dividing the project area into north and south sections. The project area comprises forested areas and swamp/marsh pockets, as well as lands to be developed. The project area also includes a system of tributary streams that is part of the Hanlon Creek watershed. These streams are the subject of the aquatic monitoring. The watercourses are shown on Map 1.

The aquatic monitoring program is being conducted primarily in the northern portion (Phase I) of the business park development, north of Laird Road. The interest in this location is based on the historic presence of brook trout (*Salvelinus fontinalis*) in the coldwater habitat provided by Tributary A1, and Tributary A north of Laird Road. One of the stations, added in 2009, is south of Laird Road, situated downstream of the outlet of Stormwater Management Pond 4.

2.1 Construction Activity

Construction commenced in late 2009 and has continued each year through to 2014. Construction activity in 2014 within Phases 1 and 2 is outlined below and highlighted on Map 2.

Phase 1, Stage 3

- Construction of building – Part of Block 8 – 425 Hanlon Creek Boulevard
- Construction of building – Part of Block 14 – 230 Hanlon Creek Boulevard

Phase 2

- Preliminary grading of Blocks 8, 9 and 26
- Laird Road overpass was in-use in 2014

No construction activity occurred within Phase 1 (Stage 2) or Phase 3 in 2014.

3.0 Methods

A total of 3 sampling sites in the northern portion of the subject property were selected during the 2006 field season. The same sites were sampled again every year from 2007 to 2012. Two sites were added in 2009 to expand the monitoring program and have been sampled continuously, including 2014. At each site, there is a benthic invertebrate sampling station (BTH) and a quantitative fish sampling station (EMS).

- Site 1 (BTH-001 and EMS-001) is located on Tributary A approximately 150m downstream of Laird Road.
- Site 2 (BTH-002 and EMS-002) is located on Tributary A immediately downstream of the confluence with Tributary A1.
- Site 3 (BTH-003 and EMS-003) is located on Tributary A1.
- Site 4 (BTH-004 and EMS-004) is located on Tributary A downstream of the Road A crossing.
- Site 5 (BTH-005 and EMS-005) is located on Tributary A upstream/south of Laird Road

Fish sampling and benthic invertebrate collections were conducted at each site, but they occurred in separate areas of the stream to facilitate collection of both parameters on the same day (Map 1).

The original selection of stations was based in part on historic knowledge of brook trout inhabitance. The stations were also positioned to help locate sources of future impacts, should any occur. To the extent possible, station selection followed the recommendation in the Ontario Stream Assessment Protocol (Stanfield 2005) to establish the upstream and downstream extents of a site at a crossover point of the thalweg (concentration of flow). The specific sections of stream were selected to represent the habitat types in the vicinity of each station.

3.1 Benthic Invertebrate Community

There are a number of advantages in sampling benthic invertebrates for water quality monitoring:

- They reflect local aquatic conditions as a result of their limited mobility;
- They integrate all the surrounding parameters of their environment into one easily assessable sampling unit;
- They integrate the physical and chemical aspects of water quality over annual time periods due to their short life spans (approximately 1 year); and
- They may indicate the probable cause of impairment because many benthic invertebrate species have known environmental sensitivities and/or tolerances.

3.1.1 Benthic Invertebrate Sampling

Sampling for the benthic invertebrate monitoring took place on August 26, 2014. It employed the sampling methodology from the Ontario Benthos Biomonitoring Network (OBBN) protocols (Jones et al 2005). Most of the following procedures have been taken from these protocols. Some of the specimen processing procedures are not covered by the OBBN protocols.

According to the OBBN methods for streams, a total of 3 subsamples are collected at each station in stream habitats: 2 from riffles, and 1 from a pool. Where riffle and pool habitats are not clearly defined (as is the case at some of the subject stations) pools and riffles can be functionally defined as slow/deep and fast/shallow sections, respectively. For wadable streams, the OBBN protocol employs a Travelling Transect Kick and Sweep method. For each subsample, a total of at least 10 linear metres of transect must be sampled in approximately 3 minutes. For small streams such as those in this study, this requires that several transects be positioned in the same riffle or pool in order to sample 10 metres of transect. Beginning at one bank and moving across each transect, the substrate is disturbed to a depth of approximately 5cm by vigorously kicking the substrate. A 500-μm-mesh D-net is held downstream of and close to the disturbed area by the person sampling. The net is held on or close to the bottom, and is swept back and forth so that dislodged invertebrates will be carried into the net. In areas of slow current, the sweeping motion is important for collecting the invertebrates into the net. A stopwatch is used to time the sampling.

When sampling is complete, the net is rinsed and the sample is placed in plastic jars. The sample is then preserved with a 75% concentration of ethyl alcohol and sent to a professional taxonomist for identification. Benthic samples collected in 2014 were processed and identified in the NRSI laboratory. Samples are identified to the lowest practical taxonomic level. Subsampling is conducted by randomly dipping a small portion of the sample from a container until at least 200 organisms are obtained. After reaching the 200th organism, the portion being sampled is completed in order to facilitate measurement of the proportion of the total sample that is subsampled and identified. The subsample proportion is determined by measuring the total sample weight/volume before identification and the remaining sample weight/volume after identification. The difference between those 2 measurements represents the portion sampled, which is recorded as a percentage of the total sample. While the OBBN protocol requires that a minimum of 100 organisms be collected, 200 organisms per subsample are collected to provide a robust sample for this program's use of the Percent Model Affinity analysis.

The OBBN data form was used to record habitat information at the benthic invertebrate sampling stations. The form includes both measured and visually estimated parameters, and facilitates comparison with other years provided the estimated parameters are treated as approximations.

3.1.2 Benthic Invertebrate Data Analysis

Analysis was performed using the Percent Model Affinity (PMA) method developed in New York State by Novak and Bode (1992). This method was adapted for southern Ontario by Dr. David Barton (1996) of the University of Waterloo.

In his 1996 paper, Dr. Barton sampled over 200 streams in southern Ontario, 69 of which were used as the reference streams for the model community. Instead of using the 7 groupings originally used by Novak and Bode (1992), Dr. Barton compared the use of model communities at the order, family, genus, and 'lowest practical' taxonomic levels. He found that there was an improvement with increasing taxonomic resolution, particularly between the family and genus levels. He also analyzed seasonal differences (Barton 1996).

The model communities used for analysis in this study are based on values from Dr. Barton for streams with mud and cobble/gravel substrates sampled in August (Barton 2007). The model community for mud substrates was used for BTH-001, BTH-003, BTH-004 and BTH-005, and the model community for cobble/gravel substrates was used for BTH-002. The family level of taxonomic resolution was used because many of the invertebrates are very small in August and September, making it difficult or impossible to identify some of the specimens beyond their family.

The equation used to determine the percent similarity of community (PSC) is as follows:

$$PSC = 100 - 0.5 \Sigma \left| a - b \right|$$

Where: a is the model community value for a taxonomic group expressed as a percentage of the organisms in the model community; and

b is the percentage of the same taxonomic group in a sample from the stream being studied.

The sample PSC value is calculated by summing the absolute differences between the family model values and the families in the sample, multiplying the sum by 0.5 and subtracting this number from 100 (Novak and Bode 1992). The sample PSC value is then compared to the critical PSC value for the chosen model community.

Each critical PSC value is effectively a lower confidence limit of the mean for the expected community. It is essentially a statistical one-tailed t-test comparing a single observation with the mean of the sample, where the P-Value = 0.05 (Zar 1999). The critical PSC values were provided by Dr. Barton along with the model community data (Barton 2007).

This index does not assign a degree of impairment or non-impairment. Rather, significant impact at a sample site is determined when the calculated sample PSC value is less than the critical PSC value. Significant impact implies that the sample community is statistically significantly different from the model community. A determination of no significant impact occurs when the calculated sample PSC value is greater than the critical PSC value (Barton 1996).

The PMA analysis was conducted for each station with the 3 subsamples (riffles and pool) combined into one sample, which is the intention of the OBBN protocol.

In addition to PMA analysis, three other indices were calculated to provide additional insight into the water quality conditions at the sampling sites. They were:

- The number of taxa present in each sample (taxonomic richness);
- The percentage of individuals in each sample belonging to the taxonomic groups Ephemeroptera, Plecoptera, and Tricoptera (EPT richness); and
- The percentage of individuals in each sample that were the dominant taxon (% dominant taxon).

Taxonomic richness is a measure used to determine the number of different species that are present in a sampled area and provide an indication of the diversity of a given site. Generally, a higher number of taxa present in a sample reflect a more diverse habitat and/or better water quality.

The percentage of Ephemeroptera, Plecoptera, and Trichoptera (EPT richness) is based on the premise that EPT taxa are less tolerant of pollution. Therefore, a higher EPT richness value suggests better water quality and/or habitat conditions.

The dominant taxon and its percentage of the sample are very helpful in characterizing the benthic community at a site. It describes an aspect of the diversity of the community, and can provide some indication of habitat and/or water quality at the site.

3.2 Fish Community

NRSI biologists conducted quantitative fish sampling at the 5 stations to provide population estimates that can be compared over the years of monitoring.

3.2.1 Fish Community Sampling

Fish sampling was conducted on August 26, 27, and 28, 2014 using a depletion sampling method that is outlined in the Ontario Stream Assessment Protocol (Stanfield 2010). At each quantitative station, the chosen stream length was isolated from the rest of the stream using block nets. The block nets were small seine nets with a mesh size similar to the size of mesh on the dip net used with the electrofisher. The rope across the bottom of the net was weighted to keep it against the bottom of the channel, and the top of the net was a floating line. The nets were secured to trees or woody material on each shore.

A 2-person electrofishing crew conducted multiple passes of the enclosed area using a Smith-Root LR-20B backpack electrofisher set to a pulsating frequency of 50Hz, and an electric potential of 150, 200, or 250 volts with current (amperes) ranging from 2.0 to 3.3A. Once collected, the fish were identified, measured on site, and released outside of the sampling area downstream of the block nets. This process was repeated until the number of individuals caught exhibited a downward trend, or a minimum of three times. The number of individual fish, and minimum and maximum lengths were recorded for each species. The water quality conditions, electrofisher settings, and number of shocking seconds for each pass were recorded. An effort was made to keep the sampling effort the same for each pass with respect to shocking seconds and netting technique.

Habitat information for the stations included classifications of adjacent lands, and basic visual estimates of macrohabitats (riffles, pools, etc.), instream vegetation, instream cover and overhead canopy shading. General flow conditions were also determined by measuring the wetted width, bankfull width, and five equally spaced depths, at five transects along the station. These habitat parameters provide a basic description of the conditions and help to understand the fish data. This information is intended to help interpret the fish community data for the quantitative stations. Because the focus of the monitoring is on the fish community, they are approximate and not intended for detailed comparison among years of monitoring.

A brook trout spawning survey was carried out during the spawning season in the fall of 2014. Three site visits were conducted, occurring on October 20, November 7, and

November 14, 2014 to document redds and observe any brook trout exhibiting spawning behaviour. The survey was conducted at several locations along Tributary A and Tributary A1 within the HCBP and covered approximately 650 m of creek.

3.2.2 Fish Community Data Analysis

The analysis of the data for the sampling stations provides estimates of the population of the fish at each station. A simple method for these calculations uses a regression of the data, which is plotted on a 2-dimensional graph with the catch from an individual fishing (1 pass) on the y-axis and the previous total catch (sum of previous passes) on the x-axis. This method is described by Zippen (1958) in the context of trapping small mammals. This calculation assumes a constant probability (P) of capture with each fishing pass. However, this method is generally considered inferior because it does not give valid estimates of the standard error of the estimated population size.

A better method employs maximum likelihood estimates, as described by Schnute (1983). This method calculates the probability of capture, and this probability can be either constant or variable. For 2014, the data collected at 4 of the 5 sampling sites were limited to 3 passes since it exhibited a consistent downward trend. Station EMS-002 required a fourth pass to achieve a consistent downward trend. These data are well suited to the maximum likelihood constant P method. Stations EMS-001, EMS-002, EMS-003, and EMS-004 met the necessary criteria required for estimating population size under the constant P method, and the population estimates are considered reliable. Although station EMS-005 exhibited a downward trend, once calculated using the constant P method the population estimate was deemed to be unreliable. For this station the linear regression method was used to produce an estimate of population size.

A computer software package called *Removal Sampling 2* by Pisces Conservation Ltd. was used to perform the calculations using the maximum likelihood – constant probability and linear regression methods. The estimated population calculations were carried out separately for each station, and estimates were made for all species combined. Capture of brook trout warrants a separate estimate, but none were captured in 2014.

4.0 Results and Discussion

4.1 Benthic Invertebrate Sampling

4.1.1 Habitat and Sampling Conditions

Station BTH-001 is situated within a white cedar – hardwood mixed swamp as defined in the Ecological Land Classification for Southern Ontario Guide (ELC, Lee et al. 1998). This swamp extends up to 100 m to the west, but a fallow agricultural field occupies land within 50 m to the southeast of the station. The riparian vegetative community is predominantly coniferous forest which was estimated to provide 75 - 100% shade. The channel is composed of runs, riffles, and pools. At the time of sampling no aquatic macrophytes or algae were observed within the channel. Woody debris and detritus was present throughout the entire site. The sampling conditions are summarized in Table 1.

Table 1. Benthic Invertebrate Sampling Conditions for Station BTH-001

Date	August 26, 2014		
Time	n/a		
Air Temperature (°C)	n/a		
Water Temperature (°C)	19.0		
Dissolved Oxygen (ppm)	n/a		
Conductivity (µS/cm)	628		
	Riffle 1	**Pool**	**Riffle 2**
Wetted Width (m)	0.9	0.9	1.2
Maximum Depth (m)	0.15	0.20	0.10
Maximum Hydraulic Head (mm)	5	2	3
Dominant Substrate	Sand	Cobble	Gravel
Second Dominant Substrate	Gravel	Clay	Sand
Total Transect Length (m)	10	10	10
Kick & Sweep Sampling Time (min:sec)	3:00	3:00	3:00
Number of Jars to Retain Sample	1	1	1

n/a = not available

Station BTH-002 is situated within a white cedar – hardwood mixed swamp (Lee et al. 1998). The vegetative community adjacent to the stream is mainly deciduous forest from 1.5 to 30 m on the west side and 1.5 to 10 m on the east side. Beyond 30 m to the west a 100 m meadow buffer separates forest from a newly developed block of land with a recently built Fusion Homes corporate office building. Beyond 10 m of forest to the east exists a strip of meadow approximately 10 m wide and a recently constructed gravel walking trail, which runs parallel to Tributary A and A1 and is fenced along both sides. The overhead canopy at this station provides an estimated 75 to 100% shade. The channel is composed of shallow riffle, pool, and run features. Within the channel aquatic macrophytes and algae are absent with some woody material and detritus present. Sampling conditions are summarized in Table 2.

Table 2. Benthic Invertebrate Sampling Conditions for Station BTH-002

Date	August 26, 2014		
Time	n/a		
Air Temperature (°C)	n/a		
Water Temperature (°C)	19.0		
Dissolved Oxygen (ppm)	n/a		
Conductivity (µS/cm)	825		
	Riffle 1	**Pool**	**Riffle 2**
Wetted Width (m)	3.4	3.2	3.4
Maximum Depth (m)	0.05	0.14	0.1
Maximum Hydraulic Head (mm)	3	0	3
Dominant Substrate	Cobble	Cobble	Cobble
Second Dominant Substrate	Gravel	Gravel	Gravel
Total Transect Length (m)	10	10	10
Kick & Sweep Sampling Time (min:sec)	3:00	3:00	2:50
Number of Jars to Retain Sample	1	2	1

n/a = not available

Station BTH-003 is situated within a white cedar – hardwood mixed swamp (Lee et al. 1998). The riparian community is dominated by deciduous forest along both banks of the creek, providing up to 100% canopy cover. To the west this vegetative community extends beyond 100m while to the east it extends to approximately 30 m. Beyond the trees a 30 m strip of meadow habitat separates the forest from the gravel walking path described under station BTH-002, which occurs within the Phase 1 construction area. The channel includes flats, runs and shallow pools. There is limited to no aquatic vegetation or algae in the channel, however woody debris and detritus are both found to be abundant throughout the site. This abundance of woody debris, provided by fallen logs and branches, adds complexity to the instream habitat. Sampling conditions for this site are provided in Table 3.

Table 3. Benthic Invertebrate Sampling Conditions for Station BTH-003

Date	August 26, 2014		
Time	n/a		
Air Temperature (°C)	n/a		
Water Temperature (°C)	12.5		
Dissolved Oxygen (ppm / %)	n/a		
Conductivity (µS/cm)	950		
	Riffle 1	**Pool**	**Riffle 2**
Wetted Width (m)	1.25	0.86	1.1
Maximum Depth (m)	0.05	0.12	0.05
Maximum Hydraulic Head (mm)	5	1	5
Dominant Substrate	Silt	Silt	Silt
Second Dominant Substrate	Sand	Sand	Sand
Total Transect Length (m)	10	10	10
Kick & Sweep Sampling Time (min:sec)	3:00	3:00	3:00
Number of Jars to Retain Sample	1	1	3

n/a = not available

Station BTH-004 is situated in a white cedar – hardwood mixed swamp (Lee et al. 1998). The vegetative community adjacent to the stream is a white cedar – hardwood mixed swamp along both banks and extending approximately 30 m. Beyond this to the west exists a section of mineral meadow marsh and fallow agricultural land. To the east this transitions to a predominantly deciduous forest and then to meadow. Beyond this lies the Phase 1 construction area which includes a gravel walking trail. Construction activities were taking place within the Phase 1 lands throughout 2014 and have been described in Section 2.1. The forest adjacent to the creek is estimated to provide approximately 75 to 100% shade over the station. The channel at this station includes a variety of shallow flats, runs and pool features. No aquatic vegetation was present in the channel at the time of sampling, however detritus and woody material were found to be present throughout the station. Sampling conditions for BTH-004 are summarized in Table 4.

Table 4. Benthic Invertebrate Sampling Conditions for Station BTH-004

Date	August 26, 2014		
Time	n/a		
Air Temperature (°C)	n/a		
Water Temperature (°C)	15.0		
Dissolved Oxygen (ppm / %)	n/a		
Conductivity (µS/cm)	712		
	Riffle 1	**Pool**	**Riffle 2**
Wetted Width (m)	1.28	2.0	1.85
Maximum Depth (m)	0.1	0.14	0.17
Maximum Hydraulic Head (mm)	2	0	3
Dominant Substrate	Sand	Silt	Sand
Second Dominant Substrate	Silt	Sand	Silt
Total Transect Length (m)	10	10	10
Kick & Sweep Sampling Time (min:sec)	3:00	3:00	3:00
Number of Jars to Retain Sample	1	2	1

Station BTH-005 is situated in a fresh – moist poplar deciduous forest which provides from 25 to 100% canopy cover, depending on the sample location. Smaller areas of reed canary grass mineral meadow marsh and willow mineral thicket swamp communities occur from 1.5 to 10 m on both sides of the channel (Lee et al. 1998). Fallow agricultural land occurs beyond 30 m to the southwest, and Laird Road is approximately 30 m to the north. Instream habitat is characterized by flat and run features with a limited amount of emergent and rooted floating vegetation within the channel. An abundance of detritus and variable amounts of woody debris were also observed. Sampling conditions are summarized in Table 5.

Table 5. Benthic Invertebrate Sampling Conditions for Station BTH-005

Date	August 20, 2013		
Time	n/a		
Air Temperature (°C)	n/a		
Water Temperature (°C)	20.0		
Dissolved Oxygen (ppm / %)	n/a		
Conductivity (µS/cm)	658		
	Riffle 1	**Pool 2**	**Riffle 3**
Wetted Width (m)	0.9	1.25	1.24
Maximum Depth (m)	0.11	0.14	0.14
Maximum Hydraulic Head (mm)	4	1	3
Dominant Substrate	Silt	Silt	Silt
Second Dominant Substrate	Sand	Sand	Sand
Total Transect Length (m)	10	10	10
Kick & Sweep Sampling Time (min:sec)	3:00	3:00	3:00
Number of Jars to Retain Sample	2	1	1

4.1.2 Benthic Invertebrate Community Data

The identification and enumeration of benthic invertebrates are summarized in tabular format in Appendix I.

The Percent Model Affinity (PMA) index calculation generates Percent Similar Community (PSC) values, which are summarized in Table 6. Values that are higher than the critical PSC value indicate no impact, while values that are lower than the critical PSC value indicate impact. The impact determinations for the years 2006 through 2013 are provided along with the 2014 results for comparison.

Table 6. Percent Similar Community Values and Impact Determination

Station	2006 Result	2007 Result	2008 Result	2009 Result	2010 Result	2011 Result	2012 Result	2013 Result	2014 Critical PSC	2014 Sample PSC	2014 Result
BTH – 001	No Impact	No Impact	No Impact	No Impact	No Impact	No Impact	No Impact	No Impact	42.12	68.08	No Impact
BTH – 002	Impact	No Impact	Impact	Impact	No Impact	Impact	Impact	Impact	50.7	45.56	Impact
BTH – 003	No Impact	No Impact	No Impact	No Impact	No Impact	No Impact	Impact	Impact	42.12	45.81	No Impact
BTH – 004	-	-	-	No Impact	No Impact	No Impact	Impact	Impact	42.12	32.30	Impact
BTH – 005	-	-	-	No Impact	No Impact	No Impact	No Impact	No Impact	42.12	35.37	Impact

The additional indices that were calculated include taxonomic richness, EPT richness, and % dominant taxon. These results are summarized in Tables 7 through 11 and are shown on Figures 3, 4, and 5. The results are discussed by station in the text that follows.

Table 7. Benthic Invertebrate Metrics for Station BTH-001 for the Years 2006 to 2014

	BTH-001								
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Taxonomic Richness	40	42	38	38	47	46	48	25	25
% EPTs	21.3	25	41.8	37.2	23.6	27.0	11.9	9.1	3.9
% Dominant Taxon	27.8	19.4	25.5	20.5	23.8	17.2	16.6	16.4	27.5

Table 8. Benthic Invertebrate Metrics for Station BTH-002 for the Years 2006 to 2014

	BTH-002								
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Taxonomic Richness	47	42	39	32	49	42	43	23	19
% EPTs	42.9	16.4	44.4	48.8	29.6	47.6	25.1	31.6	21.3
% Dominant Taxon	18.5	32.0	20.2	19.1	14.4	16.3	31.2	16.8	30.0

Table 9. Benthic Invertebrate Metrics for Station BTH-003 for the Years 2006 to 2014

	BTH-003								
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Taxonomic Richness	21	28	30	35	42	19	22	16	13
% EPTs	6.9	16.3	25.4	22.2	15.3	2.8	2.0	6.7	0.8
% Dominant Taxon	66.3	37.2	42.4	30.7	34.9	68.4	54.9	57.9	41.2

Table 10. Benthic Invertebrate Metrics for Station BTH-004 for the Years 2009 to 2014

	BTH-004								
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Taxonomic Richness	-	-	-	39	43	41	27	18	15
% EPTs	-	-	-	12.5	10.0	8.2	0.8	3.9	1.3
% Dominant Taxon	-	-	-	29.0	19.0	29.3	49.7	56.8	34.3

Table 11. Benthic Invertebrate Metrics for Station BTH-005 for the Years 2009 to 2014

	BTH-005								
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Taxonomic Richness	-	-	-	42	26	34	31	14	18
% EPTs	-	-	-	14.8	2.8	5.1	16.9	9.3	1.4
% Dominant Taxon	-	-	-	22.5	31.6	24.9	26.9	22.2	31.6

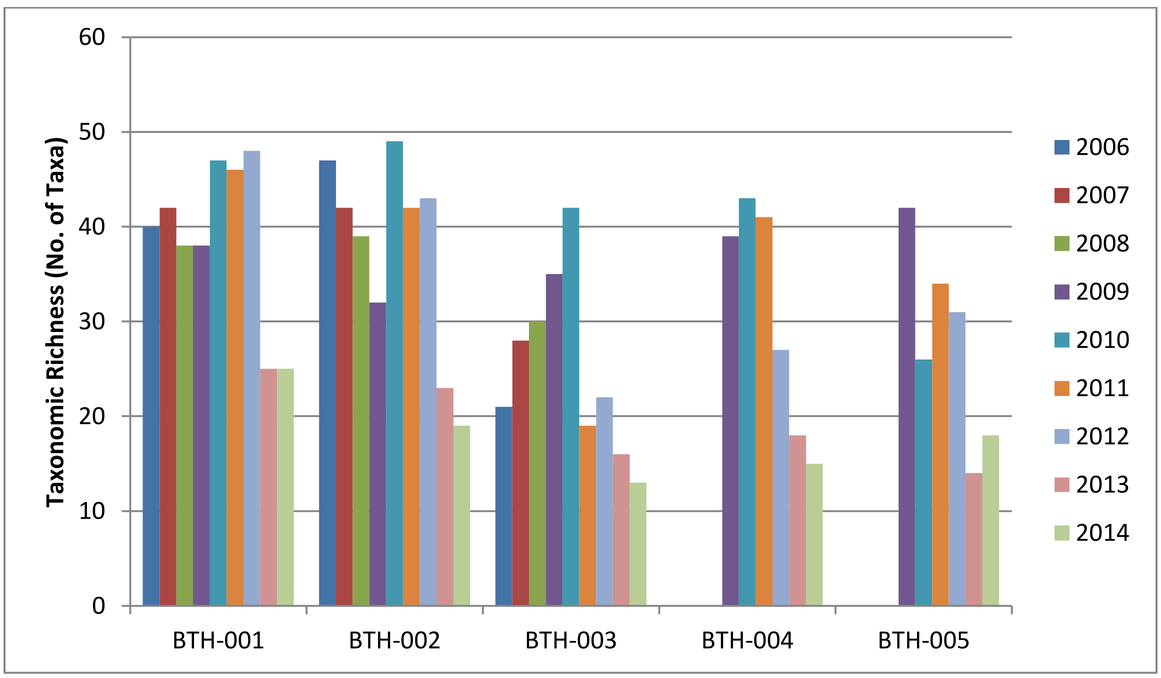

Figure 1. Benthic Invertebrate Taxonomic Richness for the Years 2006 to 2014

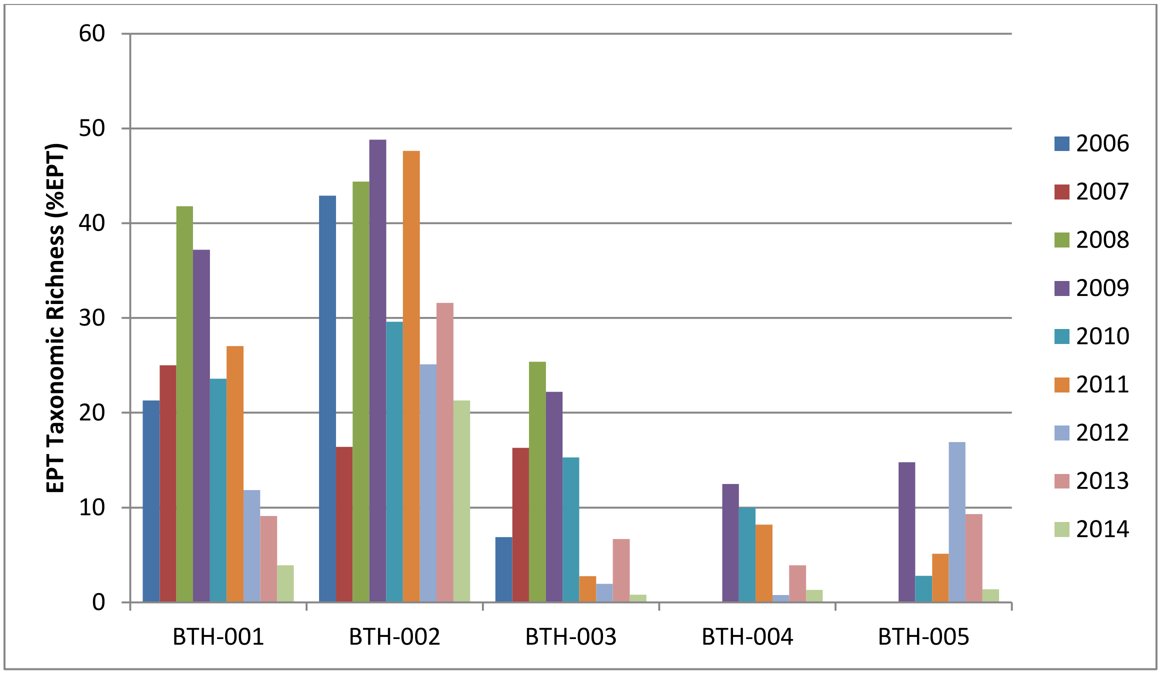

Figure 2. Benthic Invertebrate EPT Taxa Richness for the Years 2006 to 2014

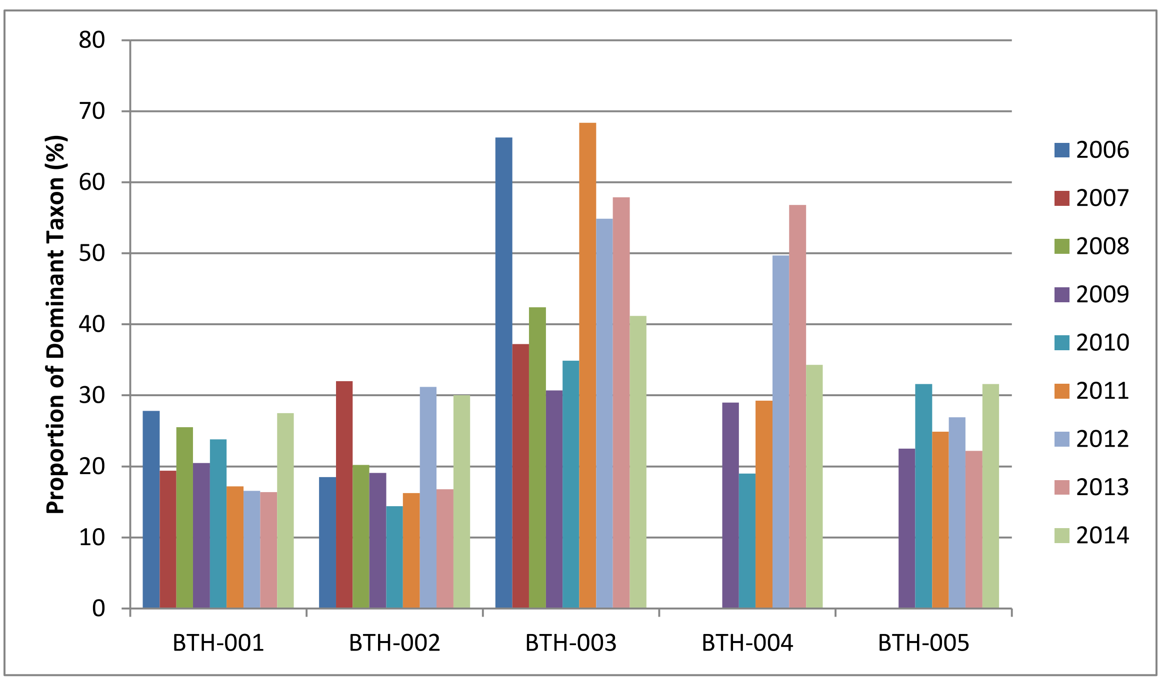

Figure 3. Benthic Invertebrate Proportion of Dominant Taxa for the Years 2006 to 2014

Station BTH-001

Taxonomic richness has remained similar at station BTH-001 throughout the 5 years of pre-construction monitoring and into the early stages of construction-phase monitoring. The number of taxa has varied from 25 to 48 with the highest level of richness recorded in 2012 (Figure 1). In 2013 a decline was noted with numbers dropping from 48 to 25, the lowest that had been observed to date. Taxonomic richness in 2014 remained low with a richness of 25, which was found for a second straight year. In 2013 it was determined that this low taxa richness was largely a function of the level of identification of the benthic invertebrates, which changed between 2012 and 2013. This appears to have continued into 2014, resulting in a similarly low richness. The changes experienced between 2012 and 2013 as well as the low taxonomic richness in 2014 have been discussed in detail in Section 4.1.3. No consistent trends have been established at BTH-001 as it relates to taxonomic richness.

The EPT richness values declined at BTH-001 from 9.1 in 2013 to 3.9 in 2014. The 2014 value was the lowest to date at this station, and continued a decline that began with a substantial decrease between 2011 and 2012. EPT richness values were slightly higher in 2006, 2007, 2010, and 2011, with minor variations between years (Figure 2). The results from 2008 and 2009 stand out as being uncharacteristically high for this station. The decline in EPT richness that has been observed between 2011 and 2014 resulted in a threshold exceedance for the third consecutive year at BTH-001. This threshold exceedance is discussed in Section 4.1.3.

The dominant taxon in 2014 belonged to *Chironominae*, a subfamily of Chironomidae. This includes a species of non-biting midge (Diptera). Species belonging to this family inhabit primarily freshwater lotic environments throughout erosional and depositional areas. They are generally burrowers and belong to the functional feeding group 'collectors', including both gatherers and scrapers (Merritt *et al*. 2008). The conditions at station BTH-001 are consistent with this generalized habitat description providing silt, sand and gravel substrates, as well as moderately abundant detritus and woody debris. *Chironominae sp.* exhibit a range of tolerances as it relates to water quality. However, in general they are indicative of fair to fairly poor water quality (Mandaville 2002). This species represented 27.5% of the total number of individuals in the sample (Figure 3) and dominated the sample for the first time in 2014. The second and third most abundant species within the sample were also subfamilies belonging to the Chironomidae family. These were *Orthocladiinae and Tanypodinae*, which comprised 18.3% and 11.4% of the sample, respectively. The remainder of the sample was largely comprised of three different species, including *Gammarus pseudolimnaeus* (10.2%), *Optioservus fastiditus* (8.4%), and *Caecidotea intermedius* (3.4%), most of which have provided a large representation within the samples through the previous years of monitoring. This site has exhibited a shift in dominant taxa since benthic sampling began in 2006. Dominant taxa previously found at this site included *Micropsectra* spp., a true fly (Dipteran) of the family Chironomidae in 2006 and 2007, *Diplectrona modesta*, a caddisfly (Trichopteran) of the family Hydropsychidae in 2008 and 2009, *Caecidotea intermedius*, a sowbug (Isopoda) of the family Asellidae in 2010 and 2011, Optioservus sp., a riffle beetle (Coleoptera) belonging to the family Elmidae in 2012, and *Orthocladiinae* spp., a subfamily of Chironomidae in 2013.

The PMA index continued to show 'no impact' in 2014. This has been a consistent result throughout all years of pre-construction monitoring, beginning in 2006, and continuing during construction-phase monitoring (Table 6). Prior to 2014 the overall results suggest that habitat and water quality conditions at station BTH-001 have generally remained consistent, aside from some expected natural variation. The decrease in EPT species at this site in 2012, 2013 and again in 2014 indicate a potential change in conditions, however based on the PMA assessment this change was not enough to characterize the site as being 'impacted'. This pattern will be further assessed during construction-phase monitoring in 2015.

Station BTH-002

Taxonomic richness at station BTH-002 was 19 in 2014. Results show a second consecutive year where the taxonomic richness has declined to the lowest levels to date. This metric experienced a steep decline in the taxonomic richness between 2012 and 2013 from 43 to 23. Previously, the lowest observed richness at BTH-002 was 32 in 2009, which increased to a high of 49 in 2010 (Figure 1). The result in 2013 was likely a function of the level of identification of the benthic invertebrates, which changed from 2012 to 2013 and continued in 2014. This change is discussed in detail in Section 4.1.3. When considering the change in the level of identification used, it appears that taxonomic richness has continued to be fairly consistent at BTH-002. The small decrease in taxonomic richness for 2014 did not exceed the benthic threshold.

The EPT richness was 21.3% in 2014, a decrease from 31.6% in 2013. This metric has shown no obvious increasing or declining trend since 2006. EPT richness has frequently been high (above 40%) with large declines noted in 2007 (16.4%), 2010 (29.6%), and most recently in 2012 (Figure 2). Further to this, it has never experienced declining richness values over consecutive years. Additionally, the lowest levels in EPT richness were seen during a pre-construction year in 2007.

The dominant taxa at station BTH-002 in 2014 was *Gammarus pseudolimnaeus*, a species of Amphipoda belonging to the family Gammaridae. Species belonging to this family occur primarily in shallow waters, resting among vegetation and debris, or slightly within soft substrate. These habitat characteristics are not entirely consistent with the substrates typically found at this site, which are dominated by cobble and gravel. However, some finer sediment was observed in addition to the presence of small amounts of woody debris and detritus, which could provide appropriate habitat for *G. pseudolimnaeus*. *G. pseudolimnaeus* are indicative of very good water quality (Mandaville 2002). This taxa represented 30.0% of the total number of individuals in the sample in 2014 and has been the dominant taxa at this station since 2012. The result for % dominant taxon has generally been lower at this station over the years of monitoring, with 2007, 2012 and 2014 being relatively high (32.0%, 31.2% and 30.0%, respectively) (Figure 3). The dominant taxonomic group has changed several times during pre-construction monitoring. In 2006, the dominant group was the genus *Sialis* of the order Megaloptera and family Sialidae. In 2007 and 2008, the dominant group was the genus *Micropsectra* of the order Diptera and family Chironomidae and in 2009 the dominant group was the genus *Cheumatopsyche spp.*, a species of caddisfly (Trichoptera) belonging to the family Hydropsychidae. In 2010 and 2011, the dominant group was *Leuctra spp.* of the order Plecoptera, a species that inhabits swift, rocky-bottomed streams, and occasionally intermittent streams (McCafferty 1981). In 2013 two species dominated the sample; *G. pseudolimnaeus* and *Diplectrona modesta*, a species of Trichoptera belonging to the Family Hydropsychidae. Hydropsychidae species were also well represented within the sample in 2014.

The PMA index in 2014 showed 'impact' for the fourth consecutive year. Results since pre-construction monitoring began in 2006 were inconsistent up until 2011 with results showing no reliable trend of 'impact' or 'no impact'. Since 2011 results have consistently indicated 'impact', which has been the most common result, with 'no impact' observed only two out of nine years of monitoring (2007 and 2010) (Table 6). Continuation of the 'impact' determinations suggests that some change has occurred. Monitoring using the PMA analysis should continue with the intention of determining whether or not a 'no impact' determination is observed again, at least on occasion.

The predominance of the 'impact' result should not be construed to mean that station BTH-002 is in poorer condition than the other stations. This station is the only station that uses the cobble/gravel model community for PMA index, and it was chosen based on the habitat characteristics of the station. Because of this difference, comparisons among the other four stations using the PMA index are not valid. The monitoring program is intended to provide temporal comparison within stations.

Station BTH-003

Taxonomic richness at station BTH-003 was 13 in 2014. This signifies a second consecutive year where taxonomic richness has decreased and a general decrease in richness that began in 2011 (Figure 1), which followed an exceptionally high year in 2010 (n = 42). The results in 2014 are the lowest that has been recorded at this site since sampling began. This result is likely a function of the level of identification of certain groups of the benthic invertebrates, which changed from 2012 to 2013 and continued in 2014. This change is discussed in detail in Section 4.1.3. Over the 5 years of monitoring prior to 2011 species richness had increased steadily by 50%, beginning in 2006 with a measure of 21 and increasing to 42 in 2010. The results observed between 2011 and 2013 appeared to be a return to the degree of taxonomic richness that was observed during preconstruction monitoring. While the results in 2014 are below preconstruction numbers, it can likely be explained by the change in the level of identification of some groups in 2013 and 2014. The high richness in 2010 included many taxa in the family Chironomidae. There were numerous individuals in that family in 2014, but they were only identified to the subfamily. This accounts for much of the reduction in taxa richness.

The EPT richness was 0.8% in 2014, a decrease from 6.7% in 2014. This is the first year where EPT richness was below 1.0% and it signifies the lowest proportion of EPT taxa that had been observed at the site to date. Results have varied through the years with an increasing trend observed during the first three years of monitoring and a decreasing trend during the five years prior to 2014 (Figure 2). In 2013 EPT richness increased slightly from 1.9% to 6.7% before declining again in 2014. The EPT richness values seen between 2011 and 2014 show levels that are lower than results from pre-construction monitoring, with the exception of 2013 which saw an increase to pre-construction levels. The decrease experienced between 2013 and 2014 resulted in the exceedance of threshold #3, which is discussed in Section 4.1.3.

The dominant taxon in 2014 was *Gammarus pseudolimnaeus*, which comprised 41.2% of the total sample (Figure 3). This marks the third consecutive year that *G. pseudolimnaeus* has been the dominant species at BTH-003. *G. pseudolimnaeus* prefers soft substrates and the shallow areas of both lotic and lentic environments. The preference of this species for depositional areas explains its abundance at station BTH-003 as this station occurs in a slow-flowing area with abundant detritus and underlying substrates dominated by silt and clay. *G. pseudolimnaeus* are indicative of very good water quality (Mandaville 2002). Prior to 2012, the dominant taxon was *Micropsectra* spp., a Dipteran species that had previously been the dominant taxon throughout all six years of pre-construction monitoring. During and following 2012 the second dominant taxa included *Micropsectra* spp. and *Orthocladiinae spp.* In 2014 there was an increase in the proportions of other species within the sample, even though there was a decrease in the taxonomic richness. This was a product of the high proportion of *G. pseudolimnaeus* within the sample.

The PMA analysis showed 'no impact' in 2014. This is a change from 2012 and 2013, both of which showed 'impact' (Table 6). Prior to 2011 the results suggested that habitat and/or water quality conditions at station BTH-003 were generally improving as evidenced by a consistent increase in species diversity (taxonomic richness) and a similarly consistent result of 'no impact'. Results in 2011 and 2012, however, suggested a change in the habitat conditions at this site leading to results that are similar to those observed in 2006. This was demonstrated through a decrease in taxonomic richness and EPT taxa richness, and a large increase in the proportion of the dominant taxon, *Micropsectra* spp in 2011, and *G. pseudolimnaeus* in 2012 and 2013. However, since this change was consistent with pre-construction monitoring results in 2006, it was attributed to natural variation. Results in 2014 show another decrease in taxonomic richness, particularly the EPT richness. At the same time, the dominant taxa is a smaller proportion of the sample, and the PMA analysis returned to ‘no impact’. It will be of interest to see if the EPT richness improves in 2015.

Station BTH-004

This was the sixth consecutive year of sampling conducted at this station, which began in 2009. Taxonomic richness at Station BTH-004 was 15 in 2014, which marks a continued decline in taxa richness that began in 2010 with 43 (Figure 1). However, beginning in 2013 this decline was likely a function of the level of identification of the benthic invertebrates, which changed from 2012 to 2013 and continued in 2014. This change is discussed in detail in Section 4.1.3. The results for this metric were relatively high between 2009 and 2011 before they began to decline in 2012.

The EPT richness was 1.3% in 2014, a decrease from 3.9% in 2013 (Figure 2). Although this is not the lowest level that has been observed at this station, it is similar to the low level from 2012, which resulted in a threshold exceedance. Results from 2013 showed a slight recovery in EPT richness values compared to those in 2012. The EPT richness values at BTH-004 have been relatively low in relation to the other four monitoring stations with the highest proportion of EPT taxa occurring in 2009 (12.5%).

The dominant taxon at BTH-004 in 2014 was *Gammarus pseudolimnaeus*, similar to Stations BTH-002 and BTH-003. As noted above, this species generally inhabits the shallow, depositional areas of both lotic and lentic environments within soft substrates and detritus. This is consistent with the habitat characteristics of BTH-004, which is comprised exclusively of fine substrates including silt and sand. Woody debris and detritus are also present throughout the site. This species represented 34.3% of the total sample in 2014 (Figure 3) and was the dominant taxa at this site for the third consecutive year, decreasing in proportion from 56.8% in 2013. Prior to 2012, the dominant taxa was identified as *Caecidotea intermedius*, a species of aquatic sowbug, which dominated the sample in 2010 and 2011. Both *C. intermedius* and *G. pseudolimnaeus* inhabit shallow waters where detritus is present and are likely to coexist in such habitat. *G. pseudolimnaeus* has consistently occurred at this station and represented the second most dominant taxa in 2011.

The PMA analysis showed “impact” at station BTH-004 in 2014 (Table 6). This signifies the third consecutive year of an ‘impact’ determination and an additional year of ‘impact’ following the exceedance of threshold 1 in 2013. This is discussed as a continued threshold exceedance in section 4.1.3.

Station BTH-005

This was the sixth consecutive year of sampling conducted at this station, which began in 2009. Taxonomic richness at Station BTH-005 was 18 in 2014, a slight increase from 14, which was observed in 2014 (Figure 1). This result is still considerably lower than what was generally observed at this station prior to 2013. A threshold exceedance was observed in 2013 following a decrease from 42, the highest value that has been noted at this site, to 14, the lowest that has been observed. This exceedance was determined most likely to be a function of the level of identification of certain groups of the benthic invertebrates, which was adjusted between 2012 and 2013.

In 2014 the EPT taxonomic richness was decreased from 9.3% to 1.4%, the lowest EPT richness value that has been observed at this station (Figure 2). This resulted in an exceedance of threshold 3 in 2014. This exceedance is discussed in Section 4.1.3. The EPT richness values at BTH-005 have fluctuated since 2006 with no obvious trends observed. The highest results were observed in 2009 and 2012 while low results were observed in 2010, 2011, and 2014. Similar to BTH-004 the EPT richness values at BTH-005 have been low relative to the other three monitoring stations.

The dominant taxon at BTH-005 was *Gammarus pseudolimnaeus* in 2014, consistent with Stations BTH-002, BTH-003, and BTH-004. *G. pseudolimnaeus* represented 31.6% of the total sample in 2014 (Figure 3). As noted above, this species generally inhabits the shallow, depositional areas of both lotic and lentic environments within soft substrates and detritus. This is consistent with the habitat characteristics of BTH-005, which is comprised of silt and sand along with detritus and some woody debris. Prior to 2014 the dominant taxa had been *Caecidotea* sp., which includes a variety of sowbug species (Asellidae spp.). The occurrence of species belonging to the family Asellidae in a diversity of habitats and their association with groundwater may explain their presence at this station. This taxa was also the second most dominant species in 2014, representing 29.6% of the sample. As seen at the majority of sampling stations, dominant taxa have generally comprised approximately 20% to 30% of the overall sample. Prior to 2014 *G. pseudolimnaeus* was the second most abundant species at BTH-005, representing 21.6% of the total sample in 2013 similar to 2012 when it comprised 10.0% of the sample.

The PMA analysis indicated 'impact' in 2014 marking the first year that this determination has been seen. Between 2009 and 2012 the PMA analysis has consistently indicated 'no impact' (Table 6). While the taxa richness and the dominant taxon remained stable in 2014, the EPT richness declined substantially and resulted in a threshold exceedance.

4.1.3 Benthic Invertebrate Threshold Analysis

The HCBP Consolidated Monitoring Program includes thresholds for various monitoring parameters. For benthic invertebrate monitoring, thresholds were developed for three benthic invertebrate metrics based on the degree of variation observed in the pre-construction monitoring data. The thresholds are as follows:

1. For the Percent Model Affinity (PMA) analysis, the threshold is an 'impact' determination at a station for 2 consecutive years following 2 consecutive years where the determination was 'no impact' at that station.
2. For Total Taxonomic Richness, the threshold is a 50% decline in the total number of taxa at a station, as compared to the results from the previous year.
3. For EPT Taxonomic Richness, the threshold is a 50% decline in the number of EPT taxa at a station, as compared to the average results from the previous 2 years.

<u>Benthic Invertebrate Threshold 1</u>

Based on the criteria for the exceedance of threshold number one, two stations experienced an exceedance in 2014 (BTH-002 and BTH-004). Station BTH-004 experienced a threshold exceedance in 2013 resulting from two consecutive years of 'impact' following two years of 'no impact'. In 2014, an 'impact' determination was made at BTH-004 for the third consecutive year.

Station BTH-002 had an 'impact' determination for the fourth consecutive year. These stations are in sequence downstream of the confluence of Tributary A and Tributary A1. The occurrence of 'impact' determinations at both of these stations suggests a change in the quality of the benthic community at these stations. Monitoring using the PMA analysis should continue with the intention of determining whether or not a 'no impact' determination is observed again at these stations.

<u>Benthic Invertebrate Threshold 2</u>

Benthic invertebrate threshold number two was not reached at any of the benthic monitoring stations in 2014. Taxonomic richness decreased at three stations (BTH-002, BTH-003, and BTH-004), however these decreases were fairly small ranging from 16.7% at BTH-004 to 18.8% at BTH-003.

In 2013, threshold two was exceeded at BTH-005. This station experienced a decrease in taxonomic richness from 31 to 14, or 55%, between 2012 and 2013. That threshold was attributed to a change in the level of identification of some groups of invertebrates from 2012 to 2013. In 2013, Chironomids were identified to sub-family level, while in 2012 they were identified to species. This resulted in a difference of approximately 20 taxa and significantly affected the taxonomic richness results for each sampling station. Thus, the threshold exceedance was not a cause for concern. In 2014, the taxonomic richness at BTH-005 experienced some recovery, increasing from 14 to 18.

<u>Benthic Invertebrate Threshold 3</u>

Benthic invertebrate threshold number three was reached at stations BTH-001, BTH-003, and BTH-005 in 2014. When compared to the averaged results from 2012 and 2013 BTH-001 experienced a reduction in EPT richness of 62.7%, BTH-003 experienced a reduction of 81.5%, and BTH-005 experienced a reduction of 89.3%, all of which exceeded the threshold of a 50.0% decrease from the average of the previous two years. EPT richness also decreased at BTH-002 and BTH-004 but not enough to result in an exceedance.

There appears to be a trend of decreasing EPT richness across the five benthic monitoring stations since 2008 and 2009 when EPT richness was highest. Stations

BTH-001, BTH-002, and BTH-003 have been monitored the longest, and they show lower EPT richness in 2006 and 2007, with the exception of BTH-002 in 2006. More recent results are lower than the EPT richness in 2006 and 2007, beginning with declines at those stations in 2011 and 2012. The year 2013 showed some recovery of the EPT richness at three of five stations. It is important to note that the change in level of identification that affected the overall taxonomic richness in 2013 did not apply to the EPT richness, because Ephemeroptera, Plecoptera and Trichoptera groups were identified to the same taxonomic resolution as the data prior to 2013.

Possible reasons for the decreasing trend in EPT richness include the drought conditions in 2012, and the continuous discharge from SWM Pond 4 beginning in late 2011. In 2012, EPT richness declined substantially at all stations except BTH-005. It is possible that the continuous discharge from SWM Pond 4, which affected the benthic sampling results for the first time in 2012, helped to maintain flows at the nearby BTH-005 during the drought conditions. However, the influence of the continuous discharge may not have been as pronounced at the other stations, and the decline in EPT richness may therefore be attributed to the drought. The monitoring report for 2012 confirms this for BTH-002, BTH-003 and BTH-004. However, it was not understood why BTH-001 had a decline in EPT richness, because it is not far downstream of BTH-005 and received similar flow augmentation from SWM Pond 5.

It is not clear why this trend has continued in 2014. Since 2012, the stations with low EPT richness have experienced similar levels or further decline. Station BTH-005 has also now declined. The continuous discharge from SWM Pond 4 continues, which has a positive effect of augmenting baseflow but also causes increases in water temperatures during the summer. Station BTH-001 is on Tributary A1, which can be considered independent of the effects of SWM Pond 4, and it exhibits declining EPT richness very clearly. The 2014 Consolidated Monitoring Report will consider potential effects in conjunction with additional monitoring information.

4.2 Fish Sampling

4.2.1 Habitat Conditions

Station EMS-001 starts and ends within a riffle feature, and pools and runs are present throughout the station. Channel substrates are dominated by gravel, along with some silt, clay, sand, and cobble. Instream habitat and cover is provided by woody debris, shallow pools and riffles, undercut banks, with some cover offered by cobble, overhanging terrestrial vegetation and backwater areas. At this monitoring station the creek exhibited a low gradient, meandering channel with a wetted width ranging from 0.75 to 2.50 m. Riffles were measured no deeper than 10 cm while a maximum depth of 20 cm was measured within one of the pools at this station.

Fish sampling was conducted on August 28, 2014. Water quality measurements were made at 1245hrs and are provided in Table 12.

Station EMS-002 was noted to have variable channel substrates consisting of mainly of cobble, gravel, sand, and pebble with some detritus, muck, and silt. Riffles marked the upstream and downstream extents of the station throughout which pools, cobble, backwater areas and aquatic vegetation provided instream habitat and cover. The creek at this location exhibited a meandering channel with a moderate gradient. Wetted widths ranged from 0.75 to 3.0 m. A maximum depth of 22 cm was measured within a pool at this station while average depths were approximately 10 cm. Dense mats of watercress were observed growing throughout nearly the entire length of the station.

Fish sampling was conducted at this location on August 27, 2014. Water quality measurements were made at 1315hrs and are provided in Table 12.

Station EMS-003 was noted to have channel substrates comprised of silt, clay, muck, and detritus with a small amount of sand. Riffles marked the upstream and downstream extents of the station throughout which instream habitat and cover were provided by woody debris, undercut banks, backwater areas, and pools. At this monitoring station the creek exhibited a low gradient through a meandering channel with a wetted width ranging from 0.75 to 1.50 m and bank-full widths from 2.0 to 3.0 m. A maximum depth of 15 cm was measured at this station.

Fish sampling was conducted at this location on August 27, 2014. Water quality measurements are provided in Table 12.

Station EMS-004 was noted to have a variety of channel substrates, dominated by sand, gravel, and cobble with small amounts of silt, and pebble. Detritus and muck were also present throughout the site. Riffles marked the upstream and downstream extents of the station. Woody debris provided the majority of instream habitat and cover but additional cover was present in the form of shallow riffles, small backwater areas, undercut banks, and cobble. At this monitoring station the creek exhibited a moderate gradient, meandering channel with a wetted width ranging from 1.25 to 2.25 m.

Fish sampling was conducted at this location on August 28, 2014. Water quality measurements are provided in Table 12.

Station EMS-005 exhibited channel substrates comprised mainly of gravel with some cobble and silt. Riffles marked the upstream and downstream extents of the station throughout which the riffles provided the majority of instream habitat and cover in the channel. Instream habitat and cover at EMS-005 was provided by a combination of small pools, riffles, undercut banks, woody debris, aquatic vegetation, and cobble. At this monitoring station the creek exhibited a moderate gradient, meandering channel with a wetted width ranging from 0.8 to 1.5 m. This station was relatively shallow measuring an average of approximately 10 cm with the deepest pool measuring a maximum depth of 25 cm.

Fish sampling was conducted at this location on August 26, 2014. Water quality measurements are provided in Table 12.

4.2.2 Fish Community Data

The water conditions during electrofishing, the settings on the electrofisher, and sampling duration are all important to document for comparing fish sampling results from year to year. This information is summarized in Table 12.

Table 12. Water Quality Measurements, Electrofishing Settings, and Shocking Times.

	EMS-001	EMS-002	EMS-003	EMS-004	EMS-005
Date	August 28, 2014	August 27, 2014	August 27, 2014	August 28, 2014	August 26, 2014
Sampling Start Time	DNC	0930	1240	DNC	DNC
Sampling End Time	DNC	DNC	DNC	DNC	DNC
Air Temperature (°C)	25.0	25.0	28.0	25.0	28.0
Water Temperature (°C)	19.0	19.0	12.5	15.0	20.0
Time Water Temp. Taken	DNC	0930	1240	DNC	DNC
Conductivity (µs/cm)	628	825	950	712	658
Dissolved Oxygen (ppm / %)	DNC	DNC	DNC	DNC	DNC
Electrofisher Type	Smith-Root LR-20B	Smith-Root LR-20B	Smith-Root LR-20B	Smith-Root LR-20B	Smith-Root LR-20B
Number of Netters	1	1	1	1	1
Voltage (V)	200	250	150	150	150
Pulsating Frequency (Hz)	50	50	50	50	50
Shocking Time (sec.) – Pass 1	552	586	399	492	642
Shocking Time (sec.) – Pass 2	518	584	377	622	595
Shocking Time (sec.) – Pass 3	480	516	407	524	570
Shocking Time (sec.) – Pass 4	N/A	384	373	N/A	N/A

DNC – Did not collect
N/A – Not applicable

During 2014 construction-phase aquatic monitoring a total of 454 individual fish were captured representing six different species: blacknose dace (*Rhinichthys obtusus*), brook stickleback (*Culaea inconstans*), central mudminnow (*Umbra limi*), creek chub (*Semotilus atromaculatus*), white sucker (*Catostomus commersonii*), and pumpkinseed (*Lepomis gibbosus*). The total catch in 2014 experienced a decrease compared to the 2013 assessment, during which 735 fish were caught. The total catch results from 2013 were uncharacteristically high for the project area and results from 2014 signify a trend back towards more 'typical' catches, comparable to what was observed during pre-construction monitoring. Prior to 2013 and 2014 the total catches ranged from 92 in 2006 to 260 in 2012. It should be noted that between 2006 and 2008 only three stations were being sampled. Between 2009 and 2014 a total of five stations were sampled, requiring careful comparison of 2014 results to results from 2006, 2007 and 2008.

A description of electrofishing results for each station in 2014 can be found below.

Population Estimates

The data collected during 2014 monitoring produced reliable statistical models for all but one electrofishing station, EMS-005. The results for 2014 are provided in Table 18 along with the results from all past years of monitoring and have been described below. Some of the results in the past years could not be reported as estimates because a statistical model could not produce a reliable estimate. In these cases the actual catch data is provided in Table 18, denoted by a single asterisk. Population estimates that were calculated using the least squares regression method are denoted in Table 18 by a double asterisk.

Station EMS-001

Electrofishing in 2014 resulted in the capture of four species. They were blacknose dace, brook stickleback, central mudminnow, and creek chub. A combined total of 95 individual fish were captured through a total of three passes. White sucker was captured for the first time at EMS-001 in 2013 but was absent again in 2014. All other species have been captured here throughout previous years of monitoring with blacknose dace being captured during every year. Northern redbelly dace (*Chrosomus eos*) and fathead minnow (*Pimephales promelas*) have also been previously captured at this station (2012 and 2011, respectively) but were absent from sampling in 2014. The detailed results are provided in Table 13.

Fish population estimates at this station have varied greatly between 2006 and 2014, and have generally been higher during construction-phase monitoring beginning in 2010 than they were during pre-construction monitoring prior to 2010. The decrease observed in 2014 occurred following three years of consistent increases. Increases were observed following 2010, during which the lowest population estimate was observed for this station (approximately 5). Prior to 2010 estimates had decreased consistently, beginning in 2007. The highest estimated population size occurred in 2013 (approximately 184) following a year of above-average precipitation. In 2014 the estimated population size decreased but was still greater than most previous monitoring years. Detailed results are provided in Table 18.

Station EMS-002

Electrofishing in 2014 resulted in the capture of six fish species and a combined total of 194 individual fish in a total of four passes. The species captured were blacknose dace, brook stickleback, central mudminnow, creek chub, white sucker, and pumpkinseed. Blacknose dace and brook stickleback have been captured at this station every year while central mudminnow and creek chub have been captured sporadically over the previous years. White sucker was captured for the third consecutive year at this station while pumpkinseed was captured for the first time within the project area. Additionally, mottled sculpin (*Cottus bairdii*), a coldwater species that was captured for the first time at this site in 2011 was not captured in 2012, 2013 or 2014. The detailed results are provided in Table 14.

The estimated fish population at EMS-002 has exhibited no obvious trend since sampling began in 2006. The estimated numbers have experienced a great deal of variation with the lowest estimate occurring in 2009 (approximately 40) and the highest estimate of approximately 241 in 2013. In 2014 this estimate decreased slightly but remained well above previous years. The estimated population at EMS-002 was nearly 211, the highest estimate of the five stations sampled in 2014. Detailed results are provided in Table 18.

Station EMS-003

Electrofishing in 2014 resulted in the capture of two fish species and a combined total of 10 fish over four passes. The species captured were blacknose dace and brook stickleback. Electrofishing results at this station indicate a low diversity of species relative to the other stations as only two species have been consistently captured here since 2007 (blacknose dace and brook stickleback). Three species were captured in 2006, which also included creek chub. The detailed results are provided in Table 15.

Population estimates at EMS-003 have been consistently low relative to the other stations within the HCBP study area. The estimate calculated in 2014 signifies a decrease from 2013 but remains similar to previous years` estimates and remains above the lowest estimates observed between 2010 and 2012. Detailed results are provided in Table 18.

Station EMS-004

Electrofishing took place at this site for the first time in 2009 and it has been sampled every year since. Electrofishing in 2014 resulted in the capture of four fish species and a combined total of 51 individual fish in three passes. The species captured included backnose dace, brook stickleback, central mudminnow, and creek chub. These four species have been consistently captured over the previous years of monitoring. White sucker was captured at this station for the first time in 2013 but was not captured during 2014 sampling. The detailed results are provided in Table 16.

Fish population estimates remained relatively consistent at EMS-004 between 2009 and 2012 ranging from approximately 29 to 58. In 2013 the population estimate increased substantially to 266, the highest estimate recorded at any of the five stations since sampling began in 2006. In 2014 the estimate decreased to approximately 63, comparable to sampling results prior to 2013. Detailed results are provided in Table 18.

Station EMS-005

Electrofishing took place at this site for the first time in 2009 and has been sampled every year since. Electrofishing in 2014 resulted in the capture of five fish species and a combined total of 104 individual fish over three passes. The species captured included blacknose dace, brook stickleback, central mudminnow, creek chub, and white sucker. Prior to 2013, this station typically contained between two and three species. In 2013, seven species were captured including fathead minnow and northern redbelly dace, which were not captured in 2014. Blacknose dace has been captured during every year of sampling at this station. Brook stickleback, central mudminnow and creek chub have also been captured throughout previous years of monitoring. The detailed results are provided in Table 17.

The population estimate at station EMS-005 in 2014 was approximately 198. This is the highest population estimate that has been observed at this station since sampling began in 2009. This also marks the fourth consecutive year that the population has increased at this station since it reached a low of approximately 2 in 2010, with the result that the population is higher than any previous year at this station. Additionally, this is the only station in 2014 that observed an increase in estimated population size compared to 2013. Detailed results are provided in Table 18.

Table 13. Fish Sampling Results for EMS-001

Fish Name		Number Captured				Fork Length (mm)	
Common	Scientific	Pass 1	Pass 2	Pass 3	Total	Smallest	Largest
Blacknose Dace	*Rhinichthys obtusus*	43	11	7	61	32	88
Brook Stickleback	*Culaea inconstans*	1	1	1	3	43	62
Central Mudminnow	*Umbra limi*	4	1	0	5	63	74
Creek Chub	*Semotilus atromaculatus*	13	11	2	26	45	100
COMBINED TOTAL (n/a = not applicable)		61	24	10	**95**		

Table 14. Fish Sampling Results for EMS-002

Fish Name		Number Captured					Fork Length (mm)	
Common	Scientific	Pass 1	Pass 2	Pass 3	Pass 4	Total	Smallest	Largest
Blacknose Dace	*Rhinichthys obtusus*	54	25	15	7	101	47	94
Brook Stickleback	*Culaea inconstans*	5	2	3	0	10	21	55
Central Mudminnow	*Umbra limi*	15	4	6	2	27	58	86
Creek Chub	*Semotilus atromaculatus*	25	18	8	2	53	54	127
Pumpkinseed	*Lepomis gibossus*	0	0	1	0	1	0	78
White Sucker	*Catostomus commersonii*	1	0	0	1	2	0	150
COMBINED TOTAL (n/a = not applicable)		100	49	33	12	**194**		

Table 15. Fish Sampling Results for EMS-003

Fish Name		Number Captured					Length (mm)	
Common	Scientific	Pass 1	Pass 2	Pass 3	Pass 4	Total	Smallest	Largest
Blacknose Dace	*Rhinichthys obtusus*	1	0	1	0	2	54	81
Brook Stickleback	*Culaea inconstans*	2	3	2	1	8	52	61
COMBINED TOTAL (n/a = not applicable)		2	3	3	1	**10**		

Table 16. Fish Sampling Results for EMS-004

Fish Name		Number Captured				Length (mm)	
Common	**Scientific**	**Pass 1**	**Pass 2**	**Pass 3**	**Total**	**Smallest**	**Largest**
Blacknose Dace	*Rhinichthys obtusus*	21	16	4	41	37	87
Brook Stickleback	*Culaea inconstans*	1	1	1	3	52	63
Central Mudminnow	*Umbra limi*	1	2	0	3	60	89
Creek Chub	*Semotilus atromaculatus*	2	0	2	4	48	59
COMBINED TOTAL		25	19	7	**51**		

Table 17. Fish Sampling Results for EMS-005

Fish Name		Number Captured				Length (mm)	
Common	**Scientific**	**Pass 1**	**Pass 2**	**Pass 3**	**Total**	**Smallest**	**Largest**
Blacknose Dace	*Rhinichthys obtusus*	11	11	8	30	47	82
Brook Stickleback	*Culaea inconstans*	1	2	0	3	44	51
Central Mudminnow	*Umbra limi*	14	14	5	33	52	68
Creek Chub	*Semotilus atromaculatus*	12	15	9	36	52	115
White Sucker	*Catostomus commersonii*	1	1	0	2	95	149
COMBINED TOTAL (n/a = not applicable)		39	43	22	**104**		

Species Biology

Six fish species were captured during the 2014 monitoring program: blacknose dace, brook stickleback, central mudminnow, creek chub, white sucker, and pumpkinseed. Descriptions of each species' habitat preferences have been provided below.

Blacknose dace are known to inhabit small to medium-sized, clear, swiftly flowing streams with gravelly substrate. These typically exhibit a moderate to steep gradient and provide a variety riffle habitat. This species is considered to be benthic and an invertivore, feeding primarily on aquatic insect larvae (Scott and Crossman 1998; Eakins 2014).

Brook stickleback are a native species to Ontario that inhabit the "clear, cold, densely vegetated waters of small streams and spring-fed ponds and may also be found along the swampy margins of beach ponds of larger lakes" (Scott and Crossman 1998). This species is considered to be benthopelagic and a planktivore/invertivore, feeding on a variety of aquatic insects and crustaceans. This species is tolerant of low dissolved oxygen, acidity and alkalinity but is generally intolerant of turbidity (Scott and Crossman 1998; Eakins 2014).

The central mudminnow is a native species common to Ontario that inhabits"heavily vegetated ponds, wetlands or pools of small creeks and quiet, shallow (0.5 m) areas of lakes with mud and organic substrates" (Eakins 2014). It is considered to be a benthic species and an invertivore, which feeds primarily on benthic invertebrates. This species is tolerant of low dissolved oxygen, low pH and high water temperatures (29°C) and is moderately tolerant of turbidity (Scott and Crossman 1998; Eakins 2014).

The creek chub is a species known to inhabit the pools of small, clear streams and rivers with preferred water temperatures around 21°C (Eakins 2014). It is considered to be benthopelagic and an invertivore/carnivore, feeding on a variety of aquatic and terrestrial invertebrates. This species is tolerant of pollution and low dissolved oxygen but is moderately intolerant of turbidity (Scott and Crossman 1998; Eakins 2014).

The white sucker is a species known to inhabit the pools and riffles of creeks and rivers, warm shallow lakes and embayments of larger lakes with preferred water temperature range from 17 to 23°C (Eakins 2014). White suckers are considered to be benthic fish and are invertivore/detritivores, feeding on a variety of benthic invertebrates. This species is tolerant of pollution and is moderately tolerant of turbidity (Scott and Crossman 1998; Eakins 2014).

Pumpkinseed typically inhabit the warm, shallow areas of lakes and ponds as well as the quiet pools of creeks and small rivers where aquatic vegetation and organic debris is present. This is a warm water species with a preferred temperature range of 22 to 30°C. Pumpkinseed are moderately tolerant of turbidity (Eakins 2014).

Five of the six fish species captured in 2014 are known previously from the monitoring program, with the exception of pumpkinseed, which was captured for the first time. All but one exhibit a cool-water thermal regime, with the exception being pumpkinseed, which prefers warmer waters (Eakins 2014). Another warmwater species, fathead minnow, was captured during sampling in 2011 and 2013 while a coldwater species, mottled sculpin, has also been previously captured in 2011. Neither species was captured in 2014. The thermal preferences of the fish captured in 2014 are generally consistent with the cool to cold water temperatures known from these watercourses, with the exception of pumpkinseed.

No trout species were captured during monitoring in 2014, which is consistent with sampling in the quantitative stations in previous years.

Population Estimates

Population estimates have fluctuated over the years with no obvious increasing or decreasing trends for Tributary A as a whole. In 2014 these estimates were seen to decrease at four of the five stations following 2013, a year that was noted to produce exceptionally high population estimates. Decreasing estimates were noted at EMS-001, EMS-002, EMS-003, and EMS-004 while an increase was seen at EMS-005 (Table 18 and Figure 6).

Table 18. Fish Population Estimates by Station for the Years 2006 to 2014

Station	2006	2007	2008	2009	2010	2011	2012	2013	2014
EMS-001	9.07	> 87*	80	48.5	5.22	59.37	129.32	184.20**	101.57
EMS-002	55.56	173.07	>53*	40.2	76.95	100.31	73.78**	241.10	210.10
EMS-003	>31*	13.89	31	32.7	>5*	8.35	1	33.03	16.05
EMS-004				29.4**	58.33	54.47	53.46	266.39	62.84
EMS-005				82.3	2.18	10.16	42.95	167.53	203.77**

* These results are approximate because the population estimate was not statistically valid.
** Estimate obtained using the least squares regression method.

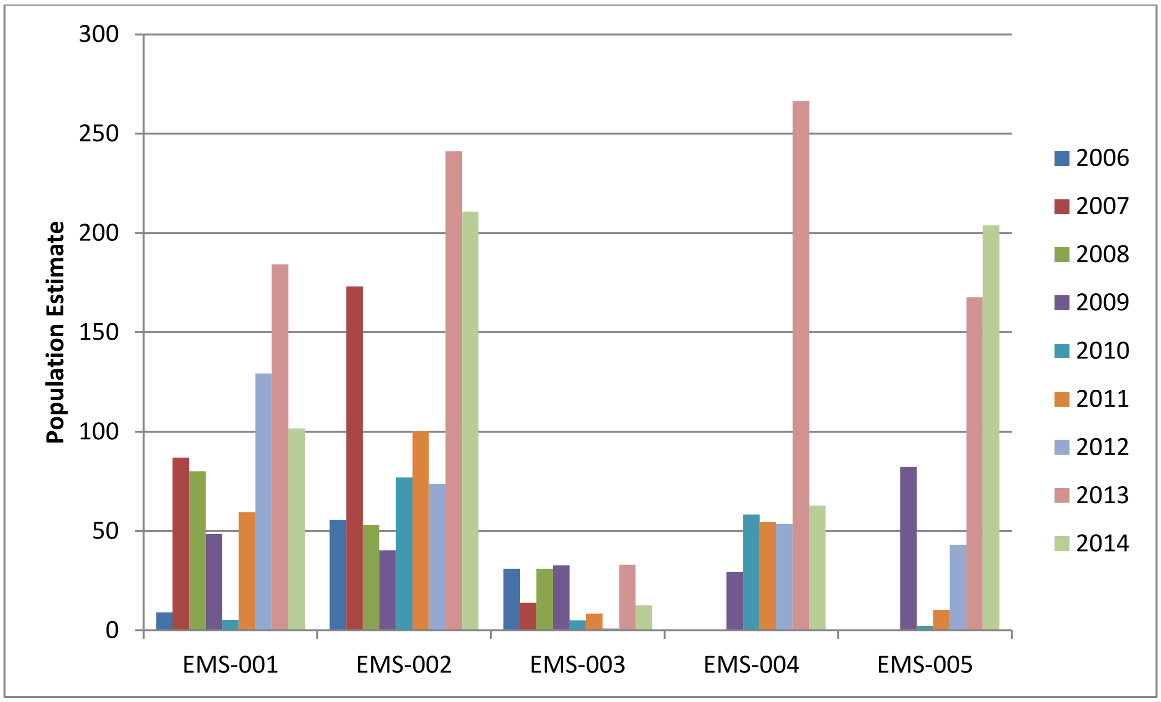

Figure 4. Population Estimates at Electrofishing Stations for the Years 2006 to 2014

<u>Brook Trout Spawning Survey</u>

Brook trout spawning surveys were conducted on three separate occasions during the fall of 2014. These were conducted on October 20, November 7, and November 14, 2014. No brook trout, brook trout redds, or evidence of brook trout spawning were observed during any of the surveys. The survey area shown on Figure 1 includes the sections of Tributary A and Tributary A1 from the swamp north of the newly constructed Road A – Tributary A crossing to the tile drain outlet located approximately 400m north of Laird Road. A summary of the survey conditions are provided in Table 19.

Table 19. 2014 Brook Trout Spawning Survey Summary

Date (2014)	Location	Start Time	End Time	Water Temperature (°C)	Air Temperature (°C)	Spawning /Evidence Observed
October 20	Tributary A	1300	1350	9.5 – 10.0	12.0	No
	Tributary A1	1350	1450	10.0 – 11.0	12.0	No
November 7	Tributary A	1130	1220	5.8 – 6.3	n/a	No
	Tributary A1	1220	1305	6.0 – 10.0	n/a	No
November 14	Tributary A	1345	1430	3.8 – 5.0	1.0	No
	Tributary A1	1430	1530	6.2 – 7.5	1.0	No

Spawning survey and habitat conditions were found to vary within the survey area based on differences in flow rates, water temperatures, substrate composition, and habitat availability.

Near the upstream extent of the area (Tributary A1) the water temperatures were similar to or slightly higher than those observed within Tributary A (see Table 19) with dominant substrates consisting of silt, muck, and detritus (primarily leaf litter). Woody debris was found throughout the channel and a small amount of watercress was also present along the margins of the creek in several locations. This section is believed to offer little to no suitable spawning habitat for brook trout. However, small schools (approximately 5 to 10) of cyprinids were utilizing the habitat throughout downstream section of Tributary A1, upstream from its confluence with Tributary A.

Throughout the centre of the site, near the new road crossing (Tributary A) water velocities were noted to be higher than upstream and substrates were dominated by cobble and gravel with small amounts of silt and sand. The water temperature here was generally the lowest observed throughout the entire reach and watercress was observed in very high abundance at this location. The water temperature at this location is typically similar to or slightly lower than what was seen in Tributary A1. This section of creek offered the most suitable spawning habitat for brook trout. A large pool, aquatic vegetation, and woody debris provided a relatively high amount of instream cover at the Hanlon Creek Boulevard crossing. Schools of small cyprinids were regularly observed throughout this section of Tributary A within the woody debris and aquatic vegetation.

Near the downstream extent of the survey area (Tributary A) substrates were similar to the upstream extent, comprised of silt and detritus. Flow at this location is evident and velocity is greater than the upstream extent, but less than what was observed throughout the middle section, which also has a higher gradient. At this location there was a high density of fallen trees and woody debris throughout the channel. It appeared that there was more woody debris throughout this section than what has been observed in past years. This added woody debris created a slight backwater effect on the upstream side of some of the log jams.

Within the surveyed reaches of the creek the most suitable brook trout habitat was observed immediately upstream and downstream of the Hanlon Creek Boulevard culvert crossing of Tributary A. This area provided appropriate spawning conditions which included predominantly gravel substrates, groundwater upwelling, and oxygenation of the water as a result of the variety of shallow riffle sections (Scott and Crossman 1998). Tributary A1 offers little to no suitable spawning habitat as result of the sand and silt substrates and detritus. Although conditions throughout Tributary A appeared suitable for brook trout spawning, no brook trout or brook trout spawning activities (ie. redds, visible eggs, etc.) were observed during any of the three spawning surveys.

4.2.3 Fish Threshold Analysis

The HCBP Consolidated Monitoring Program (NRSI 2010) includes thresholds for various monitoring parameters. For fish monitoring, pre-construction and initial construction-phase fish monitoring did not result in capture of any brook trout at the quantitative monitoring stations. A specific quantitative threshold for brook trout is not appropriate unless sufficient numbers of brook trout become established such that they can be monitored in a quantitative manner.

Although a threshold is not provided for brook trout, the overall fish community is being monitored as a surrogate indicator of the suitability of the aquatic habitat for brook trout. The results will be evaluated and compared to previous year’s data from the same stations. If any anomalies are seen, these will be addressed. Two thresholds have been developed as follows:

1. A 50% change in the number of taxa represents a potential decline in the suitability of the habitat for brook trout. Because coldwater fish communities typically have a lower species diversity, an increase in species diversity may represent a negative change in relation to the brook trout management objective. Specifically, the warm-water fish community may increase in species richness as a result of warmer water temperatures, which indicates that the habitat is becoming less suitable for brook trout. A decrease in species diversity may also represent a negative change in the suitability of the habitat for brook trout, likely attributable to some cause other than water temperature.
2. A 50% reduction in the number of fish captured represents a potential decline in the fish community resulting from habitat impacts. However, it may also represent an improvement in habitat suitability for brook trout based on temperature changes, as discussed above.

Fish Threshold 1

For the first threshold, none of the monitoring stations exhibited a 50% change in the number of taxa in 2014. This threshold has not been reached since 2011 when it was exceeded at station EMS-003.

Fish Threshold 2

For the second threshold, two stations, EMS-003 and EMS-004, exhibited a 50% reduction in the number of fish captured. At EMS-003 this occurred due to the decrease in total catch from 28 fish in 2013 to 10 fish in 2014, a 64% decline in fish capture. At EMS-004 the total catch decreased from 197 in 2013 to 51 in 2014, the equivalent of a 74% decrease.

The catch totals at EMS-003 have been consistently low since monitoring began in 2006. As a result it has a greater likelihood of exhibiting threshold exceedances than the other 4 monitoring stations since a small fluctuation in fish presence within the delineated site could result in a 50% decline. This monitoring station is located on a small groundwater-fed tributary (Tributary A1) to Hanlon Creek Tributary A, which typically provides less habitat than Tributary A. Numbers of fish have been low in the past, being similar in 2007, and lower in 2010 and 2012. Those years registered as threshold exceedances as well, but as noted the low numbers of fish predispose this site to an exceedance. Therefore, the results are considered typical for station EMS-003.

At station EMS-004, an unusually high number of fish were captured in 2013. The 74% decrease in the number of fish captured reflects a return to the numbers captured prior to 2013.

5.0 Conclusions and Recommendations

The 2014 construction-phase monitoring program was successful in providing informative aquatic monitoring data on conditions during the fifth year of construction.

A great deal of variation has been observed between 2006 and 2014 in both benthic invertebrate and fish communities within the Hanlon Creek watershed. This has largely been attributed to natural variation caused by inconsistencies in abiotic factors (ie. temperature, precipitation etc.) and stream dynamics across years in which monitoring occurred. This continued through 2014 monitoring as results indicate that a dry winter and lower than average precipitation between March and October likely impacted benthic and fish habitat suitability at many of the stations.

Two of the benthic invertebrate community thresholds identified in the HCBP Consolidated Monitoring Program (NRSI 2010) were reached in 2014. For threshold number one, two stations (BTH-002 and BTH-004) showed an ‘impact’ determination for at least 2 consecutive years following 2 consecutive years of ‘no impact’. An ‘impact’ determination was made at BTH-004 for the third consecutive year and at BTH-002 for the fourth consecutive year. At BTH-004, PMA analysis was not conducted until 2009, limiting the understanding of preconstruction conditions at this site. Station BTH-002 is the only station that uses a cobble/gravel model community for the PMA index and as such, comparisons among the other four stations using the PMA index are not valid. It should be noted that ‘impact’ determinations were made for BTH-002 during pre-construction years and results have been inconsistent between 2006 and 2014. Threshold number three was exceeded at three stations (BTH-001, BTH-003, and BTH-005) in 2014. These stations exhibited a 50.0% reduction in EPT richness compared to the average of the previous two years. The greatest decline was observed at BTH-005 (89.3% decline), while BTH-003 exhibited the second greatest decline (81.5% decline), and BTH-001 exhibited the third greatest decline (62.7% decline). There appears to be a trend of decreasing EPT richness across the five benthic monitoring stations since 2008 and 2009 when EPT richness was highest. Possible reasons for the decreasing trend in EPT richness include the drought conditions in 2012 and the continuous discharge from SWM Pond 4 beginning in late 2011.

One of the fish community thresholds identified in the HCBP Consolidated Monitoring Program (NRSI 2010) was reached in 2014. Two stations experienced a decline of more than 50% in the total number of fish captured compared to the numbers observed during the previous year. Station EMS-003 experienced a 64% decline in the total fish captured with 28 individuals captured in 2013 and 10 captured in 2014. The capture of 10 fish is considered typical of this station, with precedent noted from the years 2007, 2010 and 2012. Station EMS-004 experienced a 74% decline in the total fish captured with 197 individuals captured in 2013 and 51 captured in 2014. The 2013 results were unusually high, and the 74% decrease reflects a return to the numbers captured prior to 2013.

We recommend the following regarding future monitoring:

1. Aquatic biological monitoring should continue during the construction and build-out of the HCBP until 75% of the development is built (by area) in Phases 1, 2 and 3 of the HCBP, plus an additional 2 years. The aquatic biological monitoring will continue to be one component of the complete monitoring program, which is outlined in the HCBP Consolidated Monitoring Program.

2. Fish and benthic invertebrate monitoring should continue to occur at the 5 sites sampled in 2014.

3. A brook trout spawning survey should be conducted each year in autumn throughout the months of October and November. Even if brook trout are not captured during fish sampling at the 5 biomass stations, the spawning survey will provide an additional opportunity to observe the presence/absence of brook trout on the subject property during a different part of the brook trout life cycle.

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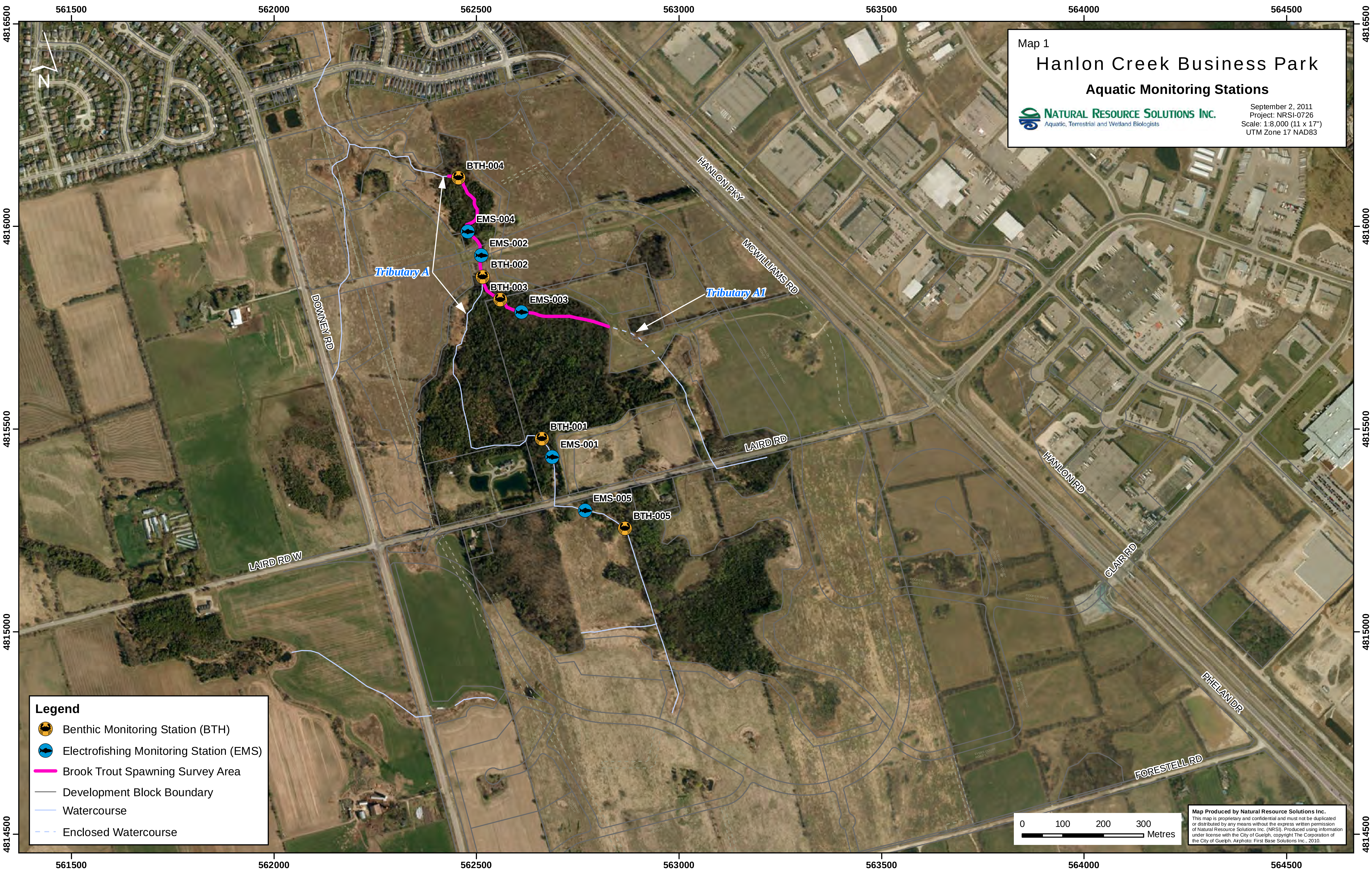
MAPS



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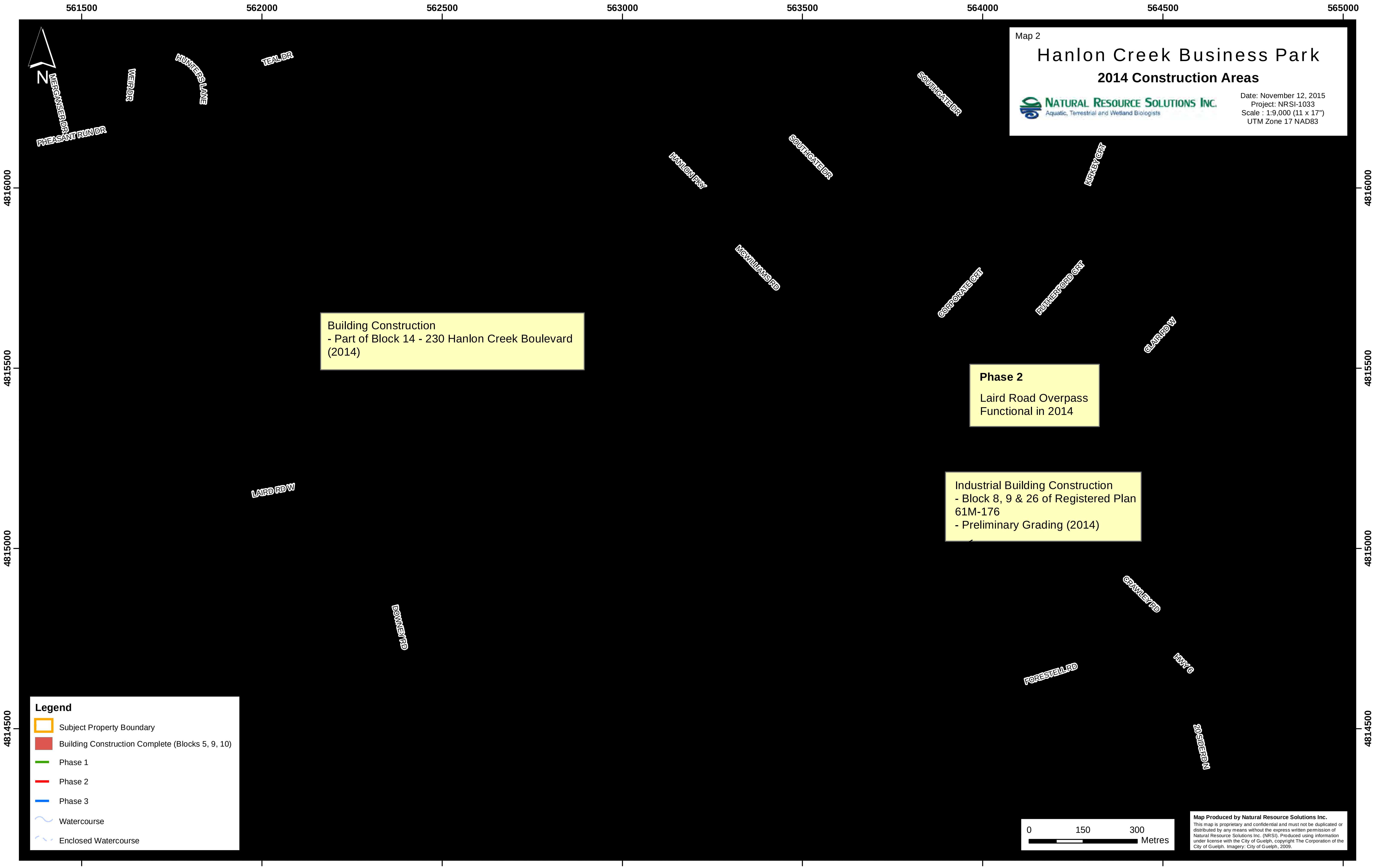

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APPENDIX I

Benthic Invertebrate Raw Data

GROUP	FAMILY	TAXON	BTH001	BTH001	BTH001	BTH001	Proportion	BTH002	BTH002	BTH002	BTH002	Proportion	BTH003	BTH003	BTH003	BTH003	Proportion
			riffle 1	pool	riffle 2			riffle 1	pool	riffle 2			riffle 1	pool	riffle 2		
			26-Aug	26-Aug	26-Aug	Pooled		26-Aug	26-Aug	26-Aug	Pooled		26-Aug	26-Aug	26-Aug	Pooled	
OLIGOCHAETA	Lumbricidae	Lumbricidae juveniles		1	3	4	1.197605				0	0		2		2	0.542005
	Tubificidae	Immatures with hair chaetae				0	0				0	0				0	0
						0	0				0	0				0	0
ACARI	Lebertiidae	Lebertia sp			2	2	0.598802				0	0				0	0
	Hygrobatidae	Hygrobates		3	5	8	2.39521				0	0				0	0
						0	0				0	0				0	0
AMPHIPODA	Gammaridae	Gammarus pseudolimnaeus	21	12	1	34	10.17964	25	57	41	123	30.07335	37	63	52	152	41.19241
						0	0				0	0				0	0
ISOPODA	Asellidae	Caecidotea intermedius	10	1	2	13	3.892216	5	11	10	26	6.356968	3	3		6	1.626016
						0	0				0	0				0	0
						0	0				0	0				0	0
COLEOPTERA	Elmidae	Dubiraphia sp larvae		2		2	0.598802				0	0				0	0
		Dubiraphia quadrinotata	6			6	1.796407	11	7	4	22	5.378973				0	0
		Optioservus sp larvae				0	0				0	0				0	0
		Optioservus fastiditus	20	8		28	8.383234		5		5	1.222494				0	0
		Stenelmis crenata				0	0				0	0				0	0
						0	0				0	0				0	0
DIPTERA	Ceratopogonidae	Ceratopogonidae type I				0	0				0	0	1		1	2	0.542005
						0	0				0	0				0	0
	Chironomidae	Sub Family				0	0				0	0				0	0
		Chironominae	7	43	42	92	27.54491	18	18	10	46	11.24694	18	23	7	48	13.00813
		Prodiamesinae			5	5	1.497006	3			3	0.733496	8			8	2.168022
		Orthocladiinae	18	20	23	61	18.26347	14	9	8	31	7.579462	18	14	23	55	14.90515
		Tanypodinae	6	8	24	38	11.37725	9	30	10	49	11.98044	10	17	17	44	11.92412
	Dixidae	Dixella				0	0				0	0	1			1	0.271003
	Empididae	Hemerodromia sp	5	3		8	2.39521				0	0				0	0
	Simulidae	Simulium sp juv				0	0				0	0				0	0
	Tabanidae	Chrysops sp	3	2	1	6	1.796407				0	0		2	1	3	0.813008
	Stratiomyidae	Odontomyia				0	0				0	0				0	0
	Tipulidae	Dicranota sp	3			3	0.898204				0	0				0	0
						0	0				0	0				0	0
EPHEMEROPTERA	Caenidae	Caenis sp				0	0				0	0				0	0
	Isonychiidae	Isonychia				0	0	1			1	0.244499				0	0
						0	0				0	0				0	0
MEGALOPTERA	Sialidae	Sialis sp	2			2	0.598802	1	7	2	10	2.444988	1	1	2	4	1.084011
						0	0				0	0				0	0
ODONATA	Aeshnidae	Boyeria sp juv	2			2	0.598802				0	0				0	0
	Aeshnidae	Aeshna				0	0				0	0				0	0
	Calopterygidae	Calopteryx sp juv	1	1		2	0.598802	1	2	2	5	1.222494				0	0
						0	0				0	0				0	0
PLECOPTERA	Leuctridae	Leuctra sp				0	0				0	0	2	1		3	0.813008
						0	0				0	0				0	0
TRICHOPTERA	Dipseudopsidae	Phylocentropus				0	0				0	0				0	0
	Glossosomatidae	Glossosoma				0	0	1			1	0.244499				0	0
	Hydropsychidae	Cheumatopsyche	2			2	0.598802	4	11	10	25	6.112469				0	0
		Diplectrona modesta	2			2	0.598802	17	6		23	5.623472				0	0
		Hydropsyche				0	0	17	9	7	33	8.06846				0	0
	Lepidostomatidae	Lepidostoma sp	2	3		5	1.497006			1	1	0.244499				0	0
	Limnephilidae	Frenesia sp				0	0		1		1	0.244499				0	0
	Molannidae	Molanna sp			1	1	0.299401				0	0				0	0
	Philopotamidae	Chimarra sp	2			2	0.598802	2			2	0.488998				0	0
	Phryganeidae	Phryganea		1		1	0.299401				0	0				0	0
						0	0				0	0				0	0
GASTROPODA	Lymnaeidae	Fossaria exigua				0	0				0	0				0	0
		Pseudosuccinea columella				0	0	2			2	0.488998				0	0
	Physidae	Physella gyrina			1	1	0.299401				0	0				0	0
						0	0				0	0				0	0
BIVALVIA	Sphaeriidae	Pisidium sp	2	1	1	4	1.197605				0	0	12	4	25	41	11.11111
						0	0				0	0				0	0
HIRUDINEA	Glossiphoniidae	Glossiphonia				0	0				0	0				0	0
						0	0				0	0				0	0
		TOTALS	114	109	111	334	100	131	173	105	409	100	111	130	128	369	100
		Number of Taxa	18	15	13	26		16	13	11	19		11	10	8	13	
		Percentage picked	16.67%	33.33%	16.13%			15.38%	5.88%	21.43%			21.43%	22.22%	33.33%		
		% Dominant Taxa					27.54491					30.07335					41.19241
		Dominant Species	DIPTERA	Chironomidae	*Chironominae*			AMPHIPODA	Gammaridae	Gammarus pseudolimnaeus			AMPHIPODA	Gammaridae	Gammarus pseudolimnaeus		
		% EPT					3.892216					21.27139					0.813008

GROUP	FAMILY	TAXON	BTH004	BTH004	BTH004	BTH004	Proportion	BTH005	BTH005	BTH005	BTH005	Proportion
			riffle 1	pool	riffle 2			riffle 1	pool	riffle 2		
			26-Aug	26-Aug	26-Aug	Pooled		26-Aug	26-Aug	26-Aug	Pooled	
OLIGOCHAETA	Lumbricidae	Lumbricidae juveniles		1		1	0.31746				0	0
	Tubificidae	Immatures with hair chaetae	3	24	8	35	11.11111		8	2	10	2.873563
						0	0				0	0
ACARI	Lebertiidae	Lebertia sp				0	0				0	0
	Hygrobatidae	Hygrobates				0	0				0	0
						0	0				0	0
AMPHIPODA	Gammaridae	Gammarus pseudolimnaeus	51	24	33	108	34.28571	35	42	33	110	31.6092
						0	0				0	0
ISOPODA	Asellidae	Caecidotea intermedius	23	10	21	54	17.14286	39	23	41	103	29.5977
						0	0				0	0
						0	0				0	0
COLEOPTERA	Elmidae	Dubiraphia sp larvae				0	0				0	0
		Dubiraphia quadrinotata				0	0				0	0
		Optioservus sp larvae				0	0				0	0
		Optioservus fastiditus	1		1	2	0.634921				0	0
		Stenelmis crenata				0	0				0	0
						0	0				0	0
DIPTERA	Ceratopogonidae	Ceratopogonidae type I		2	2	4	1.269841	1			1	0.287356
						0	0				0	0
	Chironomidae	Sub Family				0	0				0	0
		Chironominae	5	12	7	24	7.619048	13	14	8	35	10.05747
		Prodiamesinae				0	0				0	0
		Orthocladiinae	10	10	7	27	8.571429	20	8	8	36	10.34483
		Tanypodinae	4	7	12	23	7.301587	12	7	9	28	8.045977
	Dixidae	Dixella				0	0				0	0
	Empididae	Hemerodromia sp				0	0	4	1	1	6	1.724138
	Simulidae	Simulium sp juv				0	0				0	0
	Tabanidae	Chrysops sp	2	2	3	7	2.222222	2			2	0.574713
	Stratiomyidae	Odontomyia				0	0			1	1	0.287356
	Tipulidae	Dicranota sp		2		2	0.634921				0	0
						0	0				0	0
EPHEMEROPTERA	Caenidae	Caenis sp				0	0	1			1	0.287356
	Isonychiidae	Isonychia				0	0				0	0
						0	0				0	0
MEGALOPTERA	Sialidae	Sialis sp	3	3	3	9	2.857143	1	1	3	5	1.436782
						0	0				0	0
ODONATA	Aeshnidae	Boyeria sp juv				0	0				0	0
	Aeshnidae	Aeshna		1	1	2	0.634921				0	0
	Calopterygidae	Calopteryx sp juv				0	0		1		1	0.287356
						0	0				0	0
PLECOPTERA	Leuctridae	Leuctra sp				0	0				0	0
						0	0				0	0
TRICHOPTERA	Dipseudopsidae	Phylocentropus				0	0				0	0
	Glossosomatidae	Glossosoma				0	0				0	0
	Hydropsychidae	Cheumatopsyche				0	0	1			1	0.287356
		Diplectrona modesta				0	0			3	3	0.862069
		Hydropsyche				0	0				0	0
	Lepidostomatidae	Lepidostoma sp				0	0				0	0
	Limnephilidae	Frenesia sp			4	4	1.269841				0	0
	Molannidae	Molanna sp				0	0				0	0
	Philopotamidae	Chimarra sp				0	0				0	0
	Phryganeidae	Phryganea				0	0				0	0
						0	0				0	0
GASTROPODA	Lymnaeidae	Fossaria exigua				0	0	3			3	0.862069
		Pseudosuccinea columella				0	0				0	0
	Physidae	Physella gyrina				0	0				0	0
						0	0				0	0
BIVALVIA	Sphaeriidae	Pisidium sp	3	6	3	12	3.809524			1	1	0.287356
						0	0				0	0
HIRUDINEA	Glossiphoniidae	Glossiphonia		1		1	0.31746		1		1	0.287356
						0	0				0	0
		TOTALS	105	105	105	315	100	132	106	110	348	100
		Number of Taxa	10	14	13	16		12	10	11	18	
		Percentage picked	41.67%	31.25%	28.57%			11.11%	15.38%	26.67%		
		% Dominant Taxa					34.28571					31.6092
		Dominant Species	AMPHIPODA	Gammaridae	Gammarus pseudolimnaeus			AMPHIPODA	Gammaridae	Gammarus pseudolimnaeus		
		% EPT					1.269841					1.436782

APPENDIX II

Fish Population and Biomass Estimate Data

Fish Population Estimates Using Maximum Likelihood Constant P – 2006

Results	EMS-001	EMS-002	EMS-003
Estimated Population	9.07	55.56	34.81
Chi-squared	0.52	1.44	2.57
Standard error	0.3	3.05	3.82
Degrees of freedom	1	1	1
Number observed	9	52	31
Lower 95% conf. interval	9.00	52.00	31.00
Upper 95% conf. interval	9.66	61.53	42.30
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.4724 (accept)	0.2305 (accept)	0.1089 (reject)

Fish Biomass Estimates Using Maximum Likelihood Constant P – 2006

Results	EMS-001	EMS-002	EMS-003
Estimated Biomass (g)	5.03	66.10	67.21
Chi-squared	0.23	0.03	14.37
Standard error	0.19	1.30	2.05
Degrees of freedom	1	1	1
Number observed	5	65	65
Lower 95% conf. interval	5.00	65.00	65.00
Upper 95% conf. interval	5.40	68.65	71.22
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.6319 (accept)	0.8638 (accept)	0.0002 (reject)

Fish Population Estimates Using Maximum Likelihood Constant P – 2007

Results	EMS-001	EMS-002	EMS-003
Estimated Population	88.76	173.07	13.89
Chi-squared	3.42	0.44	0.23
Standard error	1.68	3.84	1.53
Degrees of freedom	1	1	1
Number observed	87	166	13
Lower 95% conf. interval	87.00	166.00	13.00
Upper 95% conf. interval	92.05	180.59	16.88
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.0646 (reject)	0.5073 (accept)	0.6315 (accept)

Fish Biomass Estimates Using Maximum Likelihood Constant P – 2007

Results	EMS-001	EMS-002	EMS-003
Estimated Biomass (g)	52.51	158.46	18.45
Chi-squared	3.97	1.06	0.02
Standard error	1.65	5.28	0.88
Degrees of freedom	1	1	1
Number observed	51	148	18
Lower 95% conf. interval	51.00	148.11	18.00
Upper 95% conf. interval	55.75	168.81	20.17
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.0463 (reject)	0.3040 (accept)	0.8853 (accept)

Fish Population Estimates Using Maximum Likelihood Constant P – 2008

Results	**EMS-001**	**EMS-002**	**EMS-003**
Estimated Population	80.02	91.84	30.93
Chi-squared	1.08	3.39	0.58
Standard error	4.17	35.62	5.22
Degrees of freedom	1	1	1
Number observed	74	53	26
Lower 95% conf. interval	74.00	53.00	26.00
Upper 95% conf. interval	88.20	161.65	41.15
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.2922 (accept)	0.0655 (reject)	0.4444 (accept)

Fish Biomass Estimates Using Maximum Likelihood Constant P – 2008

Results	**EMS-001**	**EMS-002**	**EMS-003**
Estimated Biomass (g)	55.82	105.00	36.08
Chi-squared	1.13	9.30	5.39
Standard error	4.63	1.17	9.68
Degrees of freedom	1	1	1
Number observed	50	104	27
Lower 95% conf. interval	50.00	104.00	27.00
Upper 95% conf. interval	64.89	107.29	55.05
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.2870 (accept)	0.0023 (reject)	0.0202 (reject)

Fish Population Estimates Using Maximum Likelihood Variable P – 2009

Results	EMS-001	EMS-002	EMS-003	EMS-005
Estimated Population	48.51	40.19	32.73	82.31
Chi-squared	0.56	0.35	0.24	0.17
Standard error	0.90	7.84	5.71	23.13
Degrees of freedom	1	1	1	2
Number observed	48	33	28	61
Lower 95% conf. interval	48.00	33.00	28.00	61.00
Upper 95% conf. interval	50.28	55.56	43.93	127.64
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.4550 (accept)	0.5516 (accept)	0.6234 (accept)	0.9179 (accept)

** Constant P method used for Population Estimate due to only 3 passes.

Fish Population Estimates Using Least Squares Regression – 2009

Results	EMS-004
Estimated Population	29.42
Slope	- 0.596
Y – Intercept	17.55
r^2 (Coefficient of Determination)	0.969
Residual Sum of Squares	3.916
Regression Sum of Squares	124.084
Degrees of Freedom	1
F	31.687

Fish Population Estimates Using Maximum Likelihood Constant P – 2010

Results	EMS-001	EMS-002	EMS-003	EMS-005
Estimated Population	5.22	76.95	-	2.18
Chi-squared	1.03	0.44	-	0.68
Standard error	0.67	1.17	-	0.74
Degrees of freedom	1	1	-	1
Number observed	5	76	-	2
Lower 95% conf. interval	5.00	76.00	-	2.00
Upper 95% conf. interval	6.54	79.24	-	3.63
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.3111 (accept)	0.5073 (accept)	-	0.4096 (accept)

Fish Population Estimates Using Maximum Likelihood Variable P – 2010

Results	EMS-004
Estimated Population	58.33
Chi-squared	0.47
Standard error	6.45
Degrees of freedom	1
Number observed	52
Lower 95% conf. interval	52.00
Upper 95% conf. interval	70.97
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.4929 (accept)

Fish Population Estimates Using Maximum Likelihood Constant P – 2011

Results	EMS-001	EMS-002	EMS-003	EMS-004	EMS-005
Estimated Population	59.37	100.31	8.35	54.47	10.16
Chi-squared	0.29	0.55	0.14	0.05	0.14
Standard error	7.99	7.22	9.69	5.16	2.15
Degrees of freedom	1	1	1	1	1
Number observed	49	88	5	48	9
Lower 95% conf. interval	49	88	5	48	9
Upper 95% conf. interval	75.03	114.46	27.33	64.58	14.37
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.59 (accept)	0.4565 (accept)	0.7095 (accept)	0.8316 (accept)	0.7105 (accept)

Fish Population Estimates Using Maximum Likelihood Constant P – 2012

Results	EMS-001	EMS-002	EMS-003	EMS-004	EMS-005
Estimated Population	129.32	70.08	1.00	53.46	42.95
Chi-squared	0.09	3.54	0.00	4.11	0.37
Standard error	5.57	11.05	0.00	5.78	3.55
Degrees of freedom	1	1	1	3	2
Number observed	119	55	1	46	39
Lower 95% conf. interval	119.00	55.00	1.00	46.00	39.00
Upper 95% conf. interval	140.24	91.74	1.00	64.80	49.90
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.7649 (accept)	0.0597 (**reject**)	0.9748 (accept)	0.2496 (accept)	0.8294 (accept)

Fish Population Estimates Using Least Squares Regression – 2012

Results	EMS-002
Estimated Population	73.78
Intercept (a)	27.35
Probable uncertainty of Intercept (a)	5.54
Gradient (b)	-0.37
Probable uncertainty of Gradient (b)	0.18
Chi-squared	36.24
Number observed	55.00

Fish Population Estimates Using Maximum Likelihood Constant P – 2013

Results	EMS-001	EMS-002	EMS-003	EMS-004	EMS-005
Estimated Population	190.10	241.10	33.03	266.39	159.89
Chi-squared	3.48	0.34	0.29	1.07	0.46
Standard error	5.62	18.73	5.14	27.56	9.46
Degrees of freedom	1	1	1	1	2
Number observed	178	193	28	197	139
Lower 95% conf. interval	179.09	204.40	28.00	212.37	141.34
Upper 95% conf. interval	201.11	277.81	43.11	320.40	178.44
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.0619 (**reject**)	0.5593 (accept)	0.5903 (accept)	0.3001 (accept)	0.7933 (accept)

Fish Population Estimates Using Least Squares Regression – 2013

Results	EMS-001
Estimated Population	184.20
Intercept (a)	117.69
Probable uncertainty of Intercept (a)	7.13
Gradient (b)	-0.64
Probable uncertainty of Gradient (b)	0.06
Chi-squared	52.59
Number observed	178.00

Fish Population Estimates Using Maximum Likelihood Constant P – 2014

Results	EMS-001	EMS-002	EMS-003	EMS-004	EMS-005
Estimated Population	101.57	210.10	16.05	62.84	198.34
Chi-squared	0.01	1.73	0.72	1.35	3.64
Standard error	4.16	6.72	11.68	8.95	67.17
Degrees of freedom	1	2	2	1	1
Number observed	95	194	10	51	104
Lower 95% conf. interval	95.00	196.93	10.00	51.00	104.00
Upper 95% conf. interval	109.72	223.27	38.93	80.38	329.99
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.9142 (accept)	0.4221 (accept)	0.6993 (accept)	0.2450 (accept)	0.0564 **(reject)**

Fish Population Estimates Using Least Squares Regression – 2014

Results	EMS-005
Estimated Population	203.77
Intercept (a)	43.22
Probable uncertainty of Intercept (a)	8.91
Gradient (b)	-0.21
Probable uncertainty of Gradient (b)	0.17
Chi-squared	97.29
Number observed	104.00

Hanlon Creek Business Park 2014 During-Construction

Terrestrial and Wetland Monitoring

Prepared for:
Peter Cartwright
Economic Development & Tourism Services
City of Guelph
1 Carden Street, City Hall
Guelph, ON

Project No. 1033E l December 2015

NATURAL RESOURCE SOLUTIONS INC.
Aquatic, Terrestrial and Wetland Biologists

Hanlon Creek Business Park
2014 During-Construction

Terrestrial and Wetland Monitoring

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Report submitted on December 14, 2015

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1.0 Introduction

Terrestrial and wetland monitoring in the Hanlon Creek Business Park (HCBP) has been ongoing annually since 2006. The objective of terrestrial and wetland monitoring is to identify and track any changes that may occur to the terrestrial and wetland ecology resulting from the planned industrial development of the HCBP. The terrestrial and wetland monitoring program focuses on assessing features within the entire subject property; however, it is noted that development of the Business Park is occurring in phases (Phases 1 (Stage 1 & 2), 2, and 3) (Map 1). Baseline (pre-construction) monitoring was conducted from 2006 to 2009. During construction monitoring commenced in 2010, making 2014 the fifth during construction monitoring report. The monitoring program also includes components related to the Mast-Snyder Gravel Pit, located west of the HCBP. These components of the monitoring are tied to the timing of the pit's operation and restoration.

Over time, the terrestrial and wetland monitoring program has expanded to address concerns and recommendations made by reviewing groups and agencies. The following taxonomic groups were monitored in 2014 and are documented in this report:

- Vascular flora
- Breeding Birds
- Anurans (frogs and toads)

This report provides a summary of findings from the 2014 monitoring year, as well as a comparison of the data to previous baseline and during construction years. Recommendations related to the terrestrial and wetland monitoring program are summarized.

1.1 Construction Activity

Construction commenced in late 2009 and has continued each year through to 2014. Construction activity in 2014 within Phases 1 and 2 is outlined below and highlighted on Map 2.

Phase 1, Stage 3

- Operation of commercial building I – Part of Block 5 – 500 Hanlon Creek Boulevard
- Operation of industrial building – Part of Block 9 – 345 Hanlon Creek Boulevard
- Operation of industrial building – Part of Block 10 – 265 & 285 Hanlon Creek Boulevard
- Construction of building – Part of Block 14 – 230 Hanlon Creek Boulevard

Phase 2

- Preliminary grading of Blocks 8, 9 and 26
- Laird Road overpass was in-use in 2014

No construction activity occurred within Phase 1 (Stage 2) or Phase 3 in 2014.

2.0 Methodology

Since 2006, the terrestrial and wetland monitoring program has focused on plot-based surveys to document breeding amphibians, breeding birds and vascular flora (herbaceous, shrubs and trees) as well as incidental wildlife throughout the property. Baseline soils information was collected from each of the monitoring plots in 2006.

For plot set-up and annual monitoring survey methodologies, the reader is referred to Section 3.0 in the HCBP Terrestrial and Wetland Monitoring Reports submitted to the City for previous monitoring years (NRSI 2011 – 2014).

Table 1 provides a summary of the plots that have been monitored in each year and the monitoring focus. Map 3 identifies the vegetation communities throughout the Business Park and monitoring locations.

2.1 Incidental Observations

Incidental observations of all wildlife (i.e. birds, mammals, butterflies, dragonflies, reptiles, etc.) were documented during all field visits conducted in 2014, including restoration planting warranty inspections conducted by NRSI in April, June and October in Phases 1 and 2. This included actual observations of individuals, as well as signs of animal presence, such as tracks, scat, trails, dens, etc.

Table 1. Summary of Plot Monitoring

Plot	2006				2007-2008				2009-2010				2011-2014			
	A	V	S	B	A	V	S	B	A	V	S	B	A	V	S	B
1	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
2	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
3		■	■	■		■	■	■		■	■	■		■	■	■
4	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
5		■	■	■		■	■	■		■	■	■		■	■	■
6	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
7	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
8	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
9					■	■	■	■	■	■	■	■	■	■	■	■
10									■		■		■		■	
11									■		■	■	■		■	■
12									■		■		■		■	
13									■		■		■		■	
14									■		■		■		■	
15									■		■		■		■	
16									■		■		■	■	■	■
17									■		■		■		■	
18													■	■	■	
19																■
20																■

* Soil auger sampling was discontinued after the 2012 monitoring year.

- Amphibian call count monitoring
- Vegetation monitoring
- Soil monitoring
- Breeding bird monitoring

3.0 Monitoring Results

3.1 Vascular Flora Surveys

The Ecological Land Classification (ELC) vegetation community codes and descriptions for each monitoring plot are shown on Map 3.

Refer to Appendix I for a comprehensive list of vascular flora species observed within the monitoring plots between 2006 and 2014. Table 2 lists the number of species that were observed each year. Overall, 248 different species have been observed in the vegetation monitoring plots over the course of the monitoring program. In 2014, vegetation surveys documented 3 species not previously recorded; Wool-grass (*Scirpus cyperinus var. cyperinus*) and Redtop (*Agrostis stolonifera*) in VEG-006, and a Bur Oak (*Quercus macrocarpa*) sapling in VEG-007. Specimens cannot always be identified to species level due to a lack of diagnostic features (i.e. sedge or grass species lacking an inflorescence due to the time of year).

Table 2. Number of Vegetation Species Observed by Year

Year	Number of Species
2006	97
2007	110
2008	109
2009	118
2010	124
2011	140
2012	147
2013	146
2014	136

3.1.1 Significant Vascular Flora Species

Several regionally rare species within Wellington County (Dougan 2009) have been observed, which are listed in Table 3. In 2014, Meadow Horsetail (*Equisetum pratense*) and Rough-leaved Goldenrod (*Solidago patula*) were observed and are considered rare within Wellington County. The plots from which these species and previously documented regionally rare species were observed are listed in Table 3. No federally or provincially significant species of vascular flora were observed during 2014 monitoring.

Table 3. Regionally Significant Vascular Flora Species Recorded

Common Name	Scientific Name	SRANK[1]	Wellington[2]	Year of Observation									Plot
				2006	2007	2008	2009	2010	2011	2012	2013	2014	
Bristly Buttercup	*Ranunculus hispidus var. hispidus*	S3				x							
Clearweed	*Pilea pumila*	S5	R			x					x		
Clinton's Wood Fern	*Dryopteris clintoniana*	S4	R		x			x	x				
Marsh Horsetail	*Equisetum palustre*	S5	R	x	x				x				
Meadow Horsetail	*Equisetum pratense*	S5	R	x		x	x	x	x	x		x	1,2
Mountain Ash	*Sorbus americana*	S5	R					x					
Pale Jewelweed	*Impatiens pallida*	S5	R		x	x			x				
Rough Avens	*Geum laciniatum*	S4	R		x				x	x			
Rough-leaved Goldenrod	*Solidago patula*	S5	R		x	x			x	x		x	7
Smooth Gooseberry	*Ribes hirtellum*	S5	R				x						
Witch Hazel	*Hamamelis virginiana*	S5	R			x		x					
Yellow Water-crowfoot	*Ranunculus flabellaris*	S4 ?	R			x			x				

[1]MNRF 2015a; [2]Dougan & Associates 2009

LEGEND	
SRANK	**Wellington Status**
S3 Vulnerable	R Rare
S4 Apparently Secure	
S5 Secure	
#? Uncertainty about rank	

3.1.2 Floristic Indices

A common method for evaluating and assessing natural areas is using floristic composition. This method is based on the character of a region's flora. Plant species display varying degrees of fidelity to specific habitats, which is expressed by species conservatism. Species conservatism is the degree of faithfulness a plant displays to a set of environmental conditions. The quality of a natural area is reflected in the number of conservative species found within a certain habitat (Wilhem and Ladd 1988 *In* Oldham et al. 1995). There are several floristic indices which can be used to describe the character of the vegetation in the plot. These include the Coefficient of Wetness (CW), the Coefficient of Conservatism (CC), and the Natural Area Index (NAI). All species (herbs, shrubs, and trees) from each plot are considered in these equations.

<u>Coefficient of Wetness</u>

The CW is based on wetland values given to each individual plant species. Values range from -5 to +5, where -5 indicates an obligate wetland species, and +5 indicates an obligate upland species. "0" is assigned to facultative species, those that are just as likely to be found in wetland or upland habitats. The CW values used are based on Oldham et al. (1995). Figure 1 shows the average wetness per plot, based on the wetness coefficients of all species found within a plot. All of the monitoring plots, with exception of 2 are located within wetland areas. Plot 1 continues to be the wettest plot, with an average CW score of -3.67 in 2014. Shallow, pooled water is regularly present throughout much of Plot 1 at the time of the vegetation survey. This plot supports a variety of facultative wetland shrubs and herbaceous species. Plot 3 (Sugar Maple forest) continues to exhibit the driest average CW value (0.38). Only 2 vegetation monitoring plots occur within upland ELC communities (Plot 3 and Plot 5); however in 2014 Plot 7, located within a White Cedar-Hardwood mixed swamp exhibited a positive average CW value. This plot had a positive CW value in 2009 and generally has an average CW value between 0 and -1; thus the community approaches being a forest community as opposed to a swamp based on CW values. It is also noted that the plot contains hummocks which allow for a diversity of upland and wetland herbaceous species. The remaining 8 plots are located within swamp or marsh habitat.

At Plot 16 and Plot 18, CW values have shown a drying trend between 2011 and 2014, with 2013 and 2014 CW values being similar. These plots are located in close proximity to recent development (Block 9 and Block 10) and the Hanlon Creek Boulevard. Plot 16 has consistently contained limited herbaceous vegetation, and is located in a wetland that is physically separate from the core PSW but considered part of the Hanlon Swamp Wetland Complex. Contour mapping shows that its elevation ranges from 324m to 325m above mean sea level (amsl). Monitoring well MW103 is located adjacent to this wetland where ground elevation is approximately 234m amsl. The continuous data logger has recorded groundwater elevations ranging from a low of just over 322.0m amsl in 2012 to 323.5m amsl in the spring of 2013. This demonstrates that the ground water is near the surface, yet the continuous data logger at MW103 has not measured levels at or above the ground surface since its installation in the summer of 2010. In 2014, the level at MW103 reached 323.4m in April and September. Since 2012, groundwater levels at MW103 appear to be similar to or higher than levels from 2010 to 2012. Thus, groundwater levels in the vicinity of Plot 16 do not show a trend that matches the trend in CW values.

Plots 16 and 18 were added in 2011 to monitor any changes within the wetland community due to the potential dewatering required as part of the City of Guelph SW Quadrant Class EA. Plot 18 has contained a diversity of species with good coverage of the 10x10m plot. It too is located in a small wetland that is physically separate from the core PSW but considered part of the Hanlon Swamp Wetland Complex. Contour mapping shows that its elevation is +/1 324m amsl. Monitoring Well MW118A is located approximately 80m south of this wetland and occurs where the ground elevation is also at an elevation of approximately 324m amsl. The continuous data logger has recorded groundwater elevations ranging from a low of just over 322.5m amsl in August 2011 to a high of just over 323.9m amsl in February 2009. In 2014, there was a low elevation of just under 322.9 in July and a high of almost 323.9m amsl in September. A similar low of 322.6m amsl occurred in July/August 2012. Since installation of the monitor in the summer of 2008, the groundwater at MW118A seemed to be highest in 2009, lowest in the summers of 2011 and 2012, and moderate in 2013 and 2014. This demonstrates that the ground water at MW118A can be near the surface, but often ranges from 0.5 to 1.0m below surface, and even lower at times. The low groundwater levels in the summers of 2011 and 2012 may be associated with the drying trend in CW values at Plot 18; however, the results from the years 2013 and 2014 do not demonstrate dry conditions that would easily explain the continued drying trend.

Plot 9 (cattail marsh) had shown decreasing CW values, indicating a trend of becoming wetter; however average values in 2013 (-2.71) and 2014 (-2.09) have demonstrated a return to values observed prior to 2012 when the average CW was -3.00. This plot is located in a reed-canary grass marsh and was originally added to the monitoring program to track changes as a result of the Mast-Snyder Gravel Pit to the west of the subject property. The Mast-Snyder Gravel Pit project has not been initiated, therefore, trends being observed within Plot 9 are likely attributed to natural fluctuation in precipitation from year to year. Additionally, the observation of certain species in one monitoring year (but not the next) can influence these values; Dark Green Bulrush (*Scirpus atrovirens*), for example, was observed in 2012 but has not been recorded since. With a CW of -5, species such as this would impact the overall CW value for the plot; conversely, the observation of a species with a high CW value among low CW species would influence the overall average. Plots which contain a low diversity of species are more susceptible to data fluctuations as the addition or removal of a single species can significantly impact calculations. As the average CW does not account for abundance and only provides an analysis of the overall species list, outlier species can inflate average CW values for low diversity plots.

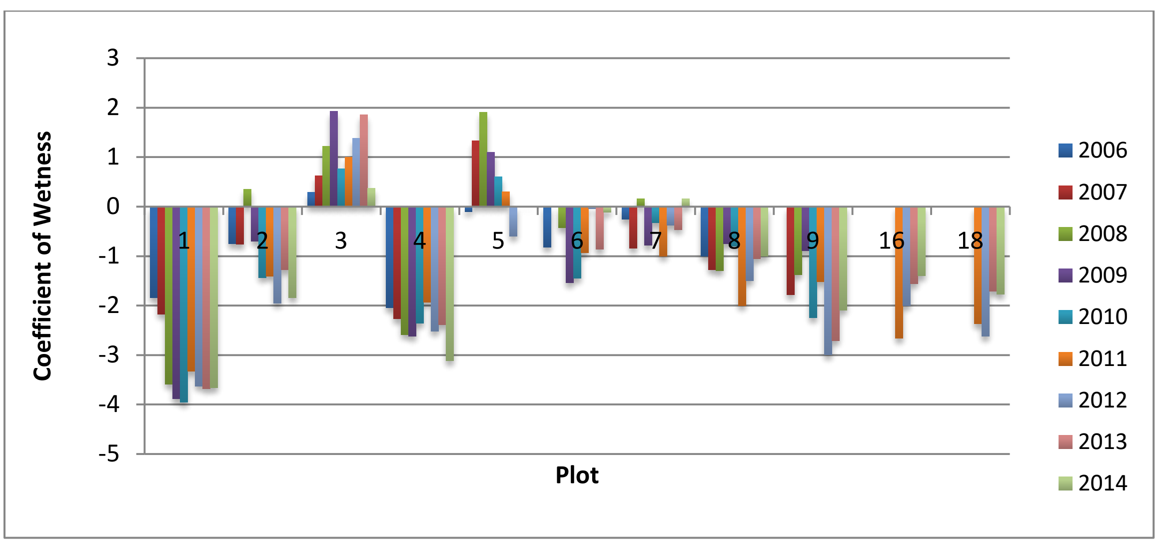

Figure 1. Coefficient of Wetness by Plot 2006 - 2014

Coefficient of Conservatism

The CC is also based on Oldham et al. (1995). Each species is given a rank between 0 and 10, based on its degree of fidelity to a range of synecological parameters (Oldham et al. 1995). Synecology is the study of the structure, development, and distribution of ecological communities. Species ranked between 0 and 3 are found in a variety of plant communities, including disturbed sites. Species ranked between 4 and 6 are those associated with a specific plant community, but which can tolerate moderate disturbance. Species ranked from 7 to 8 are found in plant communities in an advanced stage of succession with minor disturbance. Plants with a ranking of 9 or 10 have high degrees of fidelity to a narrow range of synecological factors.

The average CC per plot is shown on Figure 2. The highest CC value in 2014 was found in Plot 1 (4.76), which is within a Slender Willow thicket swamp (SWTM3-3). Plots 1 through Plot 4 and Plot 7 all exhibited average CC values between 4 and 5 in 2014 and are consistently among the highest values from year to year. Species such as Meadow Horsetail and Swamp Thistle (*Cirsium muticum*), both with a CC value of 8, provide an indication of the high quality habitat found in Plot 1 and Plot 2 respectively. The lowest average CC values continue to be found in Plot 6 (2.24), a Reed Canary Grass meadow marsh (MAMM1-3) as well as Plot 9 (2.60), a Cattail shallow marsh (MASM2-1). Neither of these plots contain trees and are likely to have been cleared and farmed historically given the abundance of non-native species and their proximity to existing (or previously existing) farm fields. These plots are dominated by early successional herbaceous species, most of which have a low CC value or no CC value for those species considered non-native to Ontario.

In most plots, the average CC value has shown minimal variation between 2006 and 2014. It should be noted that the recording of a single species with an exceptionally high or low CC value (particularly within a plot containing a relatively small number of species) can influence average CC values greatly. The decrease in average CC values in Plot 5 (17.71 in 2009 and 7.16 in 2014) may be attributed to this factor. It is believed that the variation being documented within the CC continues to be largely a result of natural fluctuations within the system including annual climate fluctuations, succession and seed dispersal and establishment.

The decrease in average CC value within Plot 16 is attributed to the disappearance of species observed in 2011 which have high CC values including Common Skullcap (*Scutellaria galericulata*), Tufted Loosestrife (*Lysimachia thyrsiflora*) and Meadow Horsetail (CC values of 6, 7 and 8 respectively). A decrease in soil moisture within the plot has likely altered the site suitability for these species which have not been observed since 2011. The very low amount of springtime precipitation in 2012 may be partially responsible for the disappearance of species with high site fidelity. There is potential that species which have disappeared from a plot may re-appear in later years through the germination of the seedbank or recolonization from areas adjacent to the plot where the plants may persist.

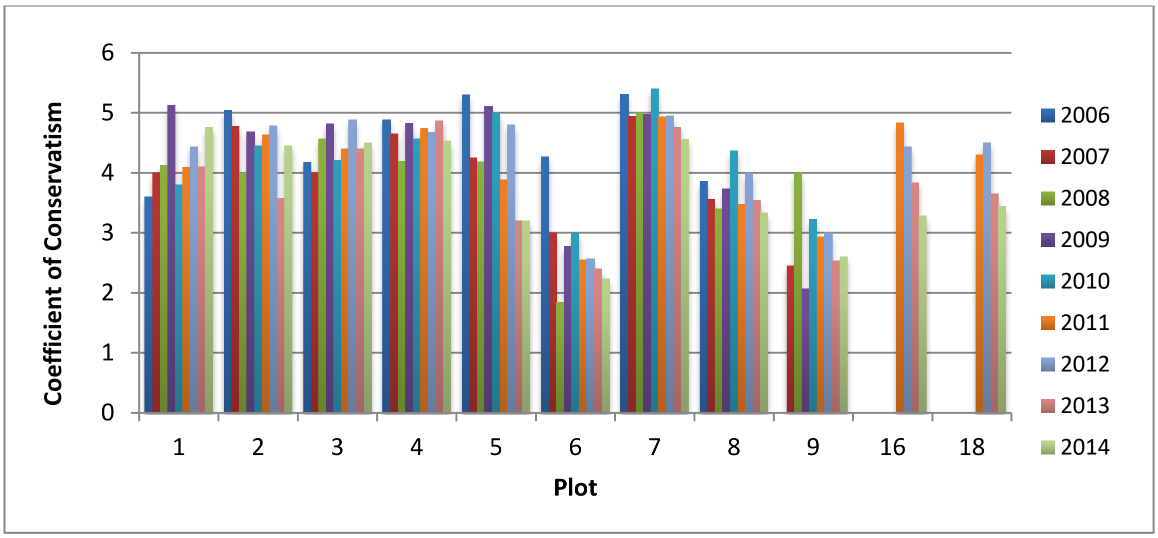

Figure 2. Coefficient of Conservatism by Plot 2006 - 2014

<u>Natural Area Index</u>

The NAI, or floristic quality index, allows the objective comparison of 2 or more natural areas or vegetation types (Oldham et al. 1995). The NAI is calculated by multiplying the average CC value by the square root of the total number of *native* species. Whereas the abundance and frequency of species can fluctuate greatly by season and year, the NAI is more stable and offers a more accurate picture. The NAI for each plot is shown on Figure 3.

The Ministry of Natural Resources and Forestry (MNRF) reports that natural areas with NAI values of over 35 are considered significant at the provincial level (Wilhelm and Ladd 1988 *in* MNR 1994). For comparison, an old successional field may score as low as <5 (Andreas et al. 2002). None of the plots within the HCBP score a value of 35 or higher. In 2014, 5 of the 11 vegetation monitoring plots were equal to or showed slight increases in NAI over 2013 values; however overall values are still generally lower than in previous years. Figure 3 shows that NAI values peaked in in the during construction monitoring years 2010 and 2011.

In 2014, the highest NAI value of 19.90 was found in Plot 2 (White Cedar – Coniferous Swamp – SWCO1-2), which is roughly average for the plot between 2006 and 2014. A high value of 26.20 was documented for the plot in 2006 with a low value of 14.97 in 2008 (both baseline monitoring years). As discussed above for CW and CC values, the addition or subtraction of a few species can have great bearing on the overall NAI value. A number of factors will influence the parameters of the NAI equation (average CC and number of native species). Some factors include plant senescence or mortality due to drought (i.e. 2012). Given that most of the vegetation monitoring plots are located within wetlands, it is likely that the dry conditions in 2012 had a lingering effect on vegetation composition. Some species may re-appear in time through the seed bank or colonization from areas adjacent to the plot. It is also possible that species that were observed in very limited numbers, such as White Beaked-rush (*Rynchospora alba*) (CC 10) in Plot 8 in 2012 may not re-appear in the near future.

The lowest NAI values in 2014 were observed in Plot 5 (7.16), Plot 6 (9.22) and Plot 9 (8.22). Each of these values can be attributed to different factors. The very low species diversity in Plot 5 had produced higher NAI values between 2006 and 2009 before a drop to present values. Meadow Horsetail (CC 8) was observed only in the 2 years which had the highest NAI for the plot; 2006 and 2009. Within a low diversity plot such as this, the influence of a single species has a notable bearing on NAI values.

Plot 6 exists within an old field meadow which contains non-native species and early successional species. The absence of high CC species within the plot maintains a low NAI value at this location. Plot 9 is dominated by Reed Canary Grass (CC 0) with abundant Broad-leaved Cattail (Typha latifolia) (CC3). With the exception of Common Buckthorn (*Rhamnus cathartica*), the plot contained all native species in 2014; however the dominance of a Reed Canary Grass and Broad-leaved Cattail produces a consistently low NAI value.

As noted in the 2013 monitoring report, the effects of the extremely dry spring in 2012 are likely to have lingering effects on the diversity of plants throughout the site. Further monitoring will determine to what degree.

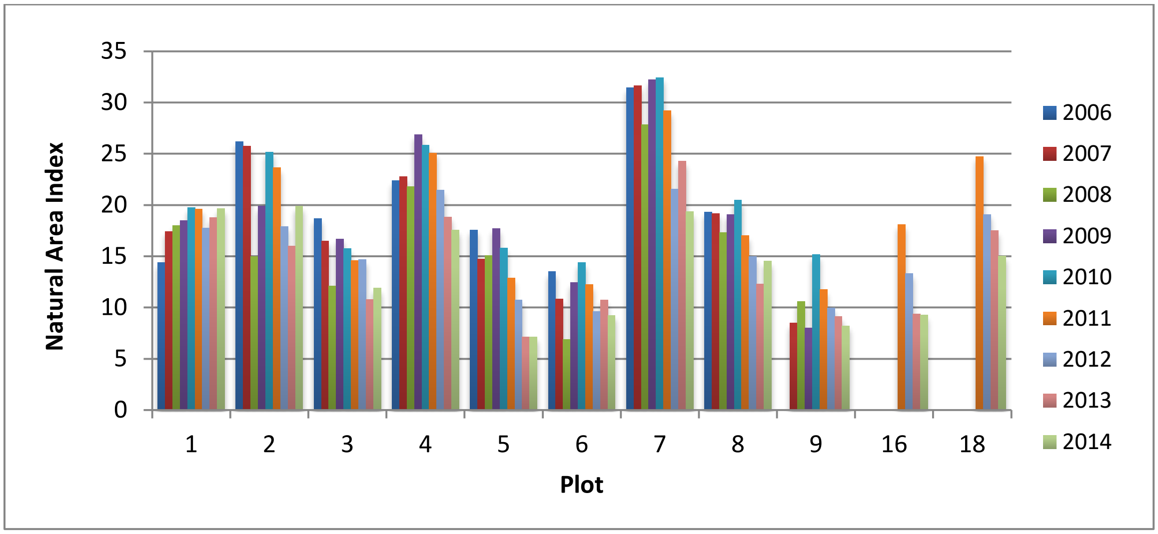

Figure 3. Natural Area Index by Plot 2006 - 2014

3.1.3 Non-Native Vegetation Species

A total of 16 non-native species were recorded within vegetation plots in 2014. The number of non-native species found in each plot is compared on Figure 4. In general, non-native species have been in present in all plots over the course of monitoring with the exception of Plot 5, a low diversity plot within which Helleborine (*Epipactis helleborine*) is present in very low numbers in some years but not others. The greatest number of non-native species was recorded in Plot 6, with 9 species documented. In 2010, 15 non-native species were documented within this plot, a number which has declined every year since. In general, the same aggressive non-native species have been observed between 2006 and 2014. Situated within a successional reed canary grass meadow marsh, Plot 6 has consistently contained a high number of non-native species due to historic disturbance (human disturbance from ATV's/machinery during pre-construction monitoring year) and close proximity to the previous agricultural land use. Non-native species such as Quack Grass (*Elymus repens*), Coltsfoot (*Tussilago farafara*) and Bird's-foot Trefoil (*Lotus corniculatus*) are clonal, somewhat aggressive and will likely continue to exclude higher quality plant species from establishing until tree canopy develops and the area is in an advanced state of succession.

The non-native species observed in 2014 do not represent any significant introductions or reductions of aggressive non-native species. Plot 2 has shown an increase in non-native species while Plot 9 has shown a decrease. In general, those species with weediness values of 2 or 3 tend to be present year after year, while less invasive species with a value of 1 are present intermittently and often in low numbers.

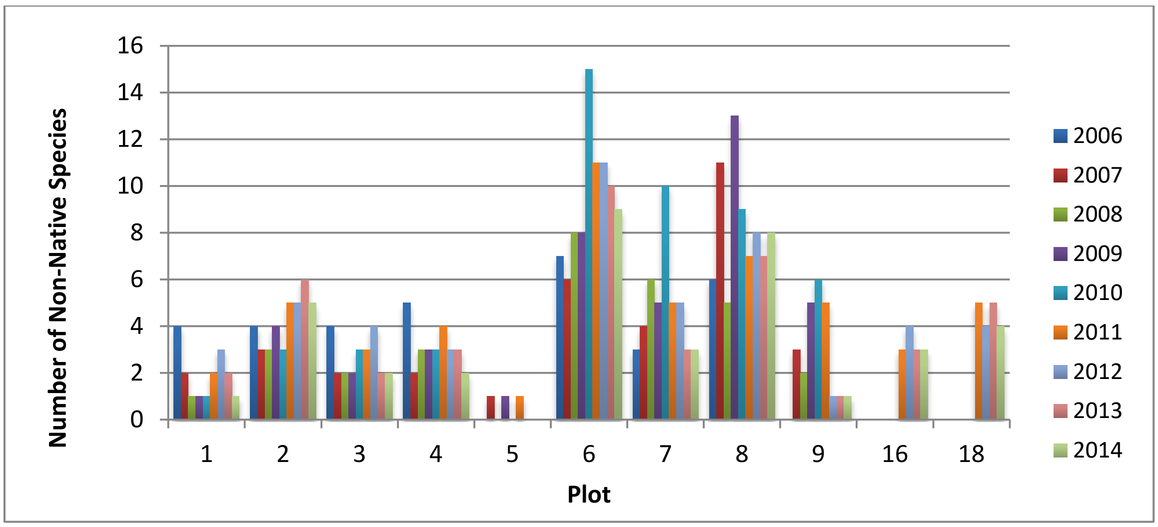

Figure 4. Non-Native Species by Plot 2006 - 2014

Between 2006 and 2013, 29 other non-native species were recorded that were not observed during the 2014 surveys. This fluctuation suggests that some non-native species may only establish for a single season before ecosystem resilience, site conditions (including drought or flooding), or a combination of both suppress the species from establishing within the plots permanently.

Certain non-native species are considered particularly invasive, and are given a score of '-3' on a weediness scale ranging from '-1' to '-3'. The invasive species found within the HCBP vegetation monitoring plots include 4 shrub species (3 species with a weediness value of -3) and 12 herbaceous species (all species with a weediness value of -2 or -1). Non-native species observed in each monitoring year is provided in Table 4. Garlic Mustard (*Alliaria petiolata*) was only recorded in Plot 18 during the 2011 monitoring year. This species is very common and invasive and it is rare to find areas that do not contain this plant. Most of the non-native species present within the monitoring plots are common agricultural weeds or shrub species which produce prolific amounts of berries that are distributed by deer, birds and other wildlife.

Common Buckthorn is the most widely dispersed non-native plant within the monitoring plots, with Glossy Buckthorn (*Rhamnus frangula*) also found in a number of plots with mesic to wet soils. Both species are tolerant of shading and fruiting specimens tend to be most common at the edge of wooded features where they receive ample sunlight. Due to the ability of these species to grow beneath a dense canopy, a groundcover of herbaceous vegetation is often interspersed with many young seedlings which germinate from the seedbank. Common buckthorn is widespread throughout southern Ontario; it is often found on calcium-rich soils and occurs in a range of soil moisture and sunlight conditions (Anderson 2012).

During vegetation surveys some species were only identified to genus as the identifying traits of the plant may not have been apparent at the time of the survey. These include an Avens species (*Geum sp.*), Sedge species (*Carex sp*.), Smartweed species (*Polygonum sp*.) and unidentifiable grass species. These species were included in the overall species count for the plot but were not included in the non-native species totals as a positive identification of the species was not possible.

3.1.4 Herbaceous Inventory

Appendix I summarizes species observed during the plot-based monitoring in the subject property from 2006 – 2014, while Appendix II summarizes vascular flora species observed within each monitoring plot in 2014. A total of 103 species of herbaceous plants were observed during the plot-based vegetation monitoring that was conducted in 2014.

Appendix III compares the herbaceous species recorded in each subplot between 2006 and 2014. Although the same subplot is monitored each year, the results vary as it is very difficult to monitor the exact same location from year to year, despite using the same bearing and location. A total of 3 herbaceous species were recorded for the first time in 2014; Redtop, Wool-grass and Bur Oak. All of these species are native and prefer wetland or bottomland habitat.

3.1.5 Shrub Inventory

The number of shrub species found within each monitoring plot and their approximate percent cover was recorded. In 2014, 22 shrub species were recorded. This number has varied over the monitoring years with low values of 15 species recorded in 2007, 2008, and 2009. Refer to Appendix IV for shrub species recorded within each monitoring plot in 2014 and Appendix V for a comparison between all years. All shrub species documented within vegetation monitoring plots had been noted in previous years with no new species additions in 2014.

3.1.6 Tree Inventory

Results from the 2014 tree inventory are found in Appendix VI. No tree species are present within Plots 1, 6 and 9. In general, the composition of tree species has remained the same throughout the monitoring period. The evaluation of tree condition (actively growing, mature or declining) is subject to observer bias and is not conducive to quantitative analysis. For example, a large DBH Eastern White Cedar with some loss of foliage or the presence of scaffold branches in the lower canopy may be considered any one of actively growing, mature or declining. Over the short-term, tree data collected within plots serves to provide insight into rates of tree mortality and the recruitment of new trees which reach 10cm DBH. Measures of canopy closure continue to provide insight into regeneration and the establishment of naturalization plantings at Plot 8. Comparison of these values from one year to the next provide insight into the resilience of the ecosystem as naturalization plantings have yet to reach heights which would influence canopy cover readings. The filling in of canopy provides benefits to the site including the maintenance of microhabitat conditions for riparian vegetation and helping to regulate water temperatures within Hanlon Creek. An assessment of tree canopy change is outlined in further detail in Section 4.2.2..

Table 4. Non-Native/Invasive Plant Species Observed

Scientific Name	Common Name	SRANK[1]	Weed	Year of Observation									Plot
				2006	2007	2008	2009	2010	2011	2012	2013	2014	
Alliaria petiolata	Garlic Mustard	SE5	-3						x				
Arctium minus	Common Burdock	SE5	-2		x								
Bromus inermis ssp. inermis	Smooth Brome	SE5	-3		x				x				
Cerastium fontanum	Larger Mouse-ear Chickweed	SE5	-1								x		
Cirsium arvense	Canada Thistle	SE5	-1	x	x	x	x	x	x	x	x	x	6
Dactylis glomerata	Orchard Grass	SE5	-1							x	x	x	8
Daucus carota	Queen Anne's Lace	SE5	-2		x		x	x	x	x	x		
Echinochloa crusgalli	Barnyard Grass	SE5	-1				x	x				x	6
Elymus repens	Quack Grass	SE5	-3			x						x	6
Epilobium hirsutum	Hairy Willow-Herb	SE5	-2				x	x	x	x	x		
Epipactis helleborine	Helleborine	SE5	-2			x	x	x		x			
Festuca arundinacea	Tall Fescue	SE5	-1								x	x	6
Frangula alnus	Glossy Buckthorn	SE5	-3	x	x	x	x	x	x	x	x	x	2,3,4,7,8, 16,18
Geranium robertianum	Herb Robert	SE5	-2	x	x	x	x	x	x				
Lactuca serriola	Prickly Lettuce	SE5		x			x						
Linaria vulgaris	Butter-and-eggs	SE5	-1			x							
Lonicera tatarica	Tartarian Honeysuckle	SE5	-3	x	x	x	x	x	x	x	x	x	2
Lotus corniculatus	Bird's-foot Trefoil	SE5	-2	x	x	x	x	x	x	x	x	x	6
Lysimachia nummularia	Moneywort	SE5	-3		x								

Scientific Name	Common Name	SRANK[1]	Weed	Year of Observation									Plot
				2006	2007	2008	2009	2010	2011	2012	2013	2014	
Lythrum salicaria	Purple loosestrife	SE5	-3							x			
Malva neglecta	Common Mallow	SE5	-1						x				
Medicago lupulina	Black Medick	SE5	-1					x	x	x	x		
Mentha X piperita	Pepper Mint	SE4	-1							x			
Nasturtium officinale	Watercress	SE?	-1				x	x	x	x	x	x	8
Phleum pratense	Timothy	SE5	-1			x		x	x	x		x	6
Plantago lanceolata	English Plantain	SE5	-1					x					
Plantago major	Common Plantain	SE5	-1					x	x				
Potentilla recta	Sulphur Cinquefoil	SE5	-2							x			
Ranunculus acris	Tall Buttercup	SE5	-2	x	x		x	x	x	x		x	6,8,9
Rhamnus cathartica	Common Buckthorn	SE5	-3	x	x	x	x	x	x	x	x	x	2,3,7,8, 16,18
Ribes rubrum	Red Currant	SE5	-2			x			x				
Rumex crispus	Curled Dock	SE5	-2			x		x	x				
Silene cucubalus	Bladder Campion		-1	x									
Solanum dulcamara	Bittersweet Nightshade	SE5	-2	x	x	x	x	x	x	x	x	x	1,2,4,8, 16,18
Sonchus arvensis	Field Sow Thistle		-1			x		x					
Taraxacum officinale	Common Dandelion	SE5	-2	x	x	x	x	x	x	x	x	x	2,3,6,8, 18
Trifolium hybridum	Alsike Clover		-1	x				x	x				
Trifolium pratense	Red Clover	SE5	-2			x							
Trifolium repens	White Clover	SE5	-1					x					
Tussilago farfara	Coltsfoot	SE5	-2	x	x	x	x	x	x	x	x	x	6,8,9

Scientific Name	Common Name	SRANK[1]	Weed	Year of Observation									Plot
				2006	2007	2008	2009	2010	2011	2012	2013	2014	
Veronica anagallis-aquatica	Water Speedwell	SE5	-1	x					x	x			
Veronica officinalis	Common Speedwell	SE5	-2			x	x		x	x			
Veronica persica	Bird's-eye Speedwell	SE4	-1							x			
Viburnum opulus	Guelder-rose	SE4	-1							x	x	x	8

[1]MNRF 2015a

LEGEND	
SRANK	
SE4 Uncommon but not rare	SE Exotic Species
SE5 Common, widespread, and abundant	? Rank Uncertainty

The tree data collected from 2006 to 2014 is compared in Appendix VII. No notable changes were observed in tree species composition or tree health within any of the monitoring plots between 2014 and previous years. While signs of Emerald Ash Borer (*Agrilus planipennis*) (EAB) were not noted in 2013 or 2014 monitoring, it is very likely that the insect is present within the subject property and widespread decline of Ash (*Fraxinus* spp.) trees, including those within monitoring plots, may be inevitable. A total of 9 Ash trees are tagged and were monitored in 2014; of these, 5 are in decline, 1 is a snag and 3 are actively growing. These are comprised of Black Ash (*Fraxinus nigra*), White Ash (*F. americana*) and Green Ash (*F. pensylvanica*) growing in Plots 2, 3, 4, 7 and 18. A loss of canopy cover due to Ash decline is likely to make for a temporary increase in herbaceous species both in numbers and in vigour. In time the canopies of existing trees including White Cedar (*Thuja occidentalis*), Red Maple (*Acer rubrum*) and Yellow Birch (*Betula alleghaniensis*) will fill in those areas where Ash was once present. Canopy openings will also spur the growth of shrub and tree saplings.

3.2 Vegetation Threshold Assessment

The thresholds for vegetation and soils established in the *HCBP Consolidated Monitoring Program* (NRSI 2010) are as follows:

- A change in herbaceous cover by more than 25%.
- A change in species diversity by more than 25%.
- A change in canopy cover by more than 25%.

3.2.1 Herbaceous Cover

The average herbaceous cover per year and plot is shown on Figure 5. The herbaceous cover fluctuates annually, with large fluctuations observed even in the pre-construction monitoring years (2006 - 2009). Herbaceous cover in 2014 was generally consistent with the overall average among monitoring years with notable increases between 2013 and 2014 in Plot 2 and Plot 8. Plot 8 contains several Black Ash which have been in decline (or become snags) in recent years. This change in canopy cover, coupled with tree removal several years prior, has likely allowed for additional herbaceous species representation. Within Plot 2, Spotted Jewelweed comprises much of the herbaceous cover within the plot, potentially due to favourable temperatures and soil moisture for the species.

Plot 1 has shown a high degree of variability in herbaceous cover which is likely attributed to the fluctuation in seasonal standing water within the plot. Years in which snowmelt and spring rainfall are abundant maintain a water depth of 10-20cm in the plot by July monitoring. Other years were rainfall is less abundant allow for more exposed detritus and soil as well as larger hummocks all of which allow for greater numbers and cover of herbaceous vegetation. Herbaceous cover in Plot 3 rebounded slightly in 2014 (16.3%) from 2012 (11.1%) and 2013 (9.1%). Herbaceous cover in this plot is primarily influenced by the presence of Ostrich Fern (*Matteuccia struthiopteris*) which seemingly flourishes in some years while being quite reduced in others. As discussed in previous monitoring reports, reductions in the cover of this species may be due to a number of factors, including deer browse or fluctuations in climatic conditions between years. Effort has been made to conduct vegetation plot monitoring at the same time in July each year to allow for comparison. It is inferred that seasonal soil moisture and deer browse are likely the 2 factors most influential to the percentage cover of this species in any given year.

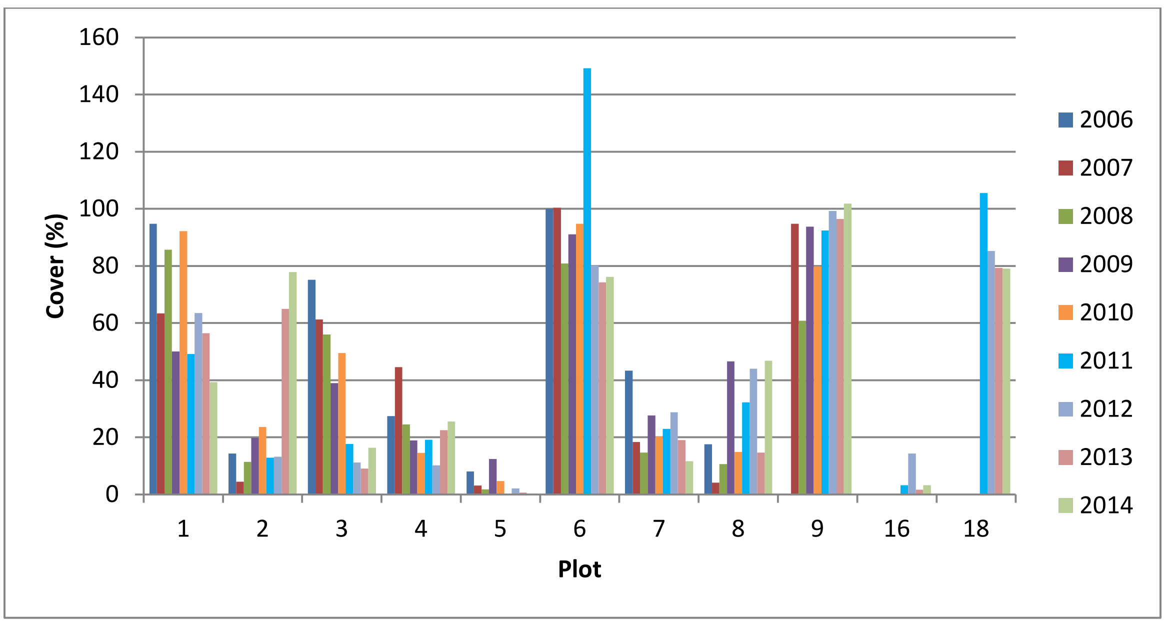

Figure 5. Change in Herbaceous Cover from 2006 to 2014

Figure 6 represents the change in herbaceous cover from 2010 to 2014 in comparison to the preconstruction year average (2006 - 2009). A range bar on the preconstruction average column on Figure 6 shows an increase and decrease of 25% herbaceous cover. An increase in herbaceous cover is generally ecologically positive, as it means greater plant matter for foraging and refuge for wildlife, as well as a generally well-being of the plant species. An increase can be negative if the increase is due to an introduction or expansion of a non-native and/or invasive species. A decrease in herbaceous cover is generally negative as it means removal of soil protection, forage and refuge material, as well as a potential decrease in biodiversity. A decrease in herbaceous cover can be due to direct vegetation removal, annual fluctuation in climatic conditions, trampling, erosion, flooding, or the effects of sun (sun scald) or salt, among other reasons.

Variation in the percentage cover of any given species may also vary from year-to-year as a result of observer bias. By employing standard plot sampling methodology a relatively accurate value can be obtained for the percentage cover of a species; however variability in the perception of coverage is inevitable. By having vegetation surveys completed by the same NRSI biologists from year to year (where possible), bias in the perception of cover has been minimized.

In 2014, the 25% threshold was exceeded in Plots 1, 2, 3 and 8. In both Plots 2 and 8 the exceedance was positive with native herbaceous cover in these plots increasing substantially since the pre-construction phase. Plot 1 showed a decrease below the threshold which has been attributed to the presence of standing water within the plot during vegetation surveys. The extended hydroperiod within Plot 1 is not seen as a negative scenario as it provides wildlife habitat and maintains the existing vegetation community which is adapted to hydric soils. The presence of standing water within this plot is not likely to be attributed in any way to the limited construction that has been completed within Phase 2 (Map 2).

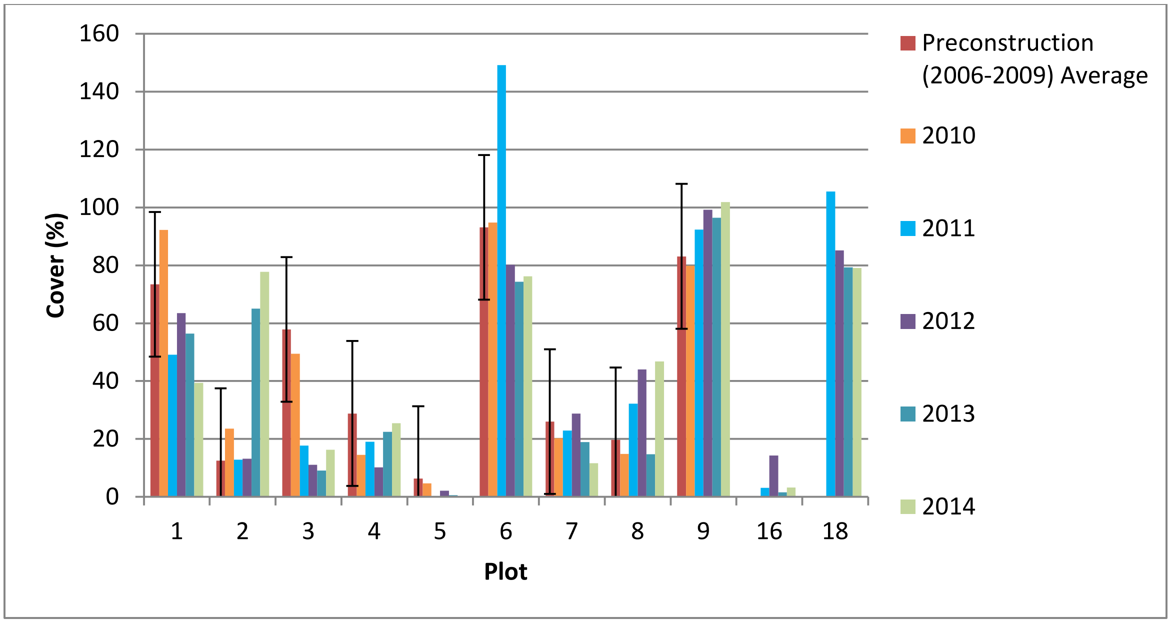

Figure 6. Change in Herbaceous Cover from 2010 to 2014 Compared to Preconstruction Average

(The range bar shows a 25% increase and decrease in herbaceous cover)

Plot 3 was identified in previous monitoring reports due to the reduction in herbaceous cover within the plot; in particular Ostrich Fern. Data collected in 2014 shows a slight rebound in herbaceous species coverage which has been attributed to ample soil moisture in the spring of 2014 and potentially a reduction in herbivores; in particular White-tailed Deer. While groundwater monitoring does not currently have any wells or piezometers in close proximity to Plot 3, overall groundwater levels and gradients for nearby monitoring points do not indicate any notable fluctuations in hydrology between 2003-2014 aside from the low water table conditions observed in early 2012 (Banks Groundwater Engineering 2015). Ostrich Fern has a coefficient of wetness of -3, indicating that it requires moisture to survive and flourish; thus increases in groundwater levels (and precipitation) will contribute to the resurgence of this species and the overall herbaceous cover in Plot 3.

Given the proportion of vegetation monitoring plots located within wetland habitats on site (9 of 11 plots); the fluctuation of groundwater levels will continue to influence changes in vegetation composition within the plots.

3.2.2 Vegetation Species Diversity

Species diversity is the number of species observed within each monitoring plot. Figure 7 compares vegetation species diversity per plot for each year since 2006. All species recorded in each plot are included in this data, which includes herbaceous species recorded within the overall 10x10m plot, not just within the subplots. Species diversity in 2014 is generally representative of the 8 year average with some minor increases and decreases within various plots. A notable decrease was observed in Plot 7 which dropped from 47 species in 2013 to 29 species in 2014. While many species within the plot are noted to be "Rare" with only 1-2 stems present, hardy species such as Field Horsetail (*Equisetum arvense*), Woodland Strawberry (*Fragaria vesca*) and Bitter Nightshade (*Solanum dulcamara*) are still very likely to be present, potentially just beyond the plot boundary. The current approach of taking a compass bearing of 0°, 45° and 90° to determine corner locations based on the permanent t-bar stake is the likely cause of the inclusion and exclusion of certain species located at the fringe of each plot.

Variation in species diversity can likely be attributed to a number of factors including changes in climatic conditions which may encourage or discourage sensitive species.

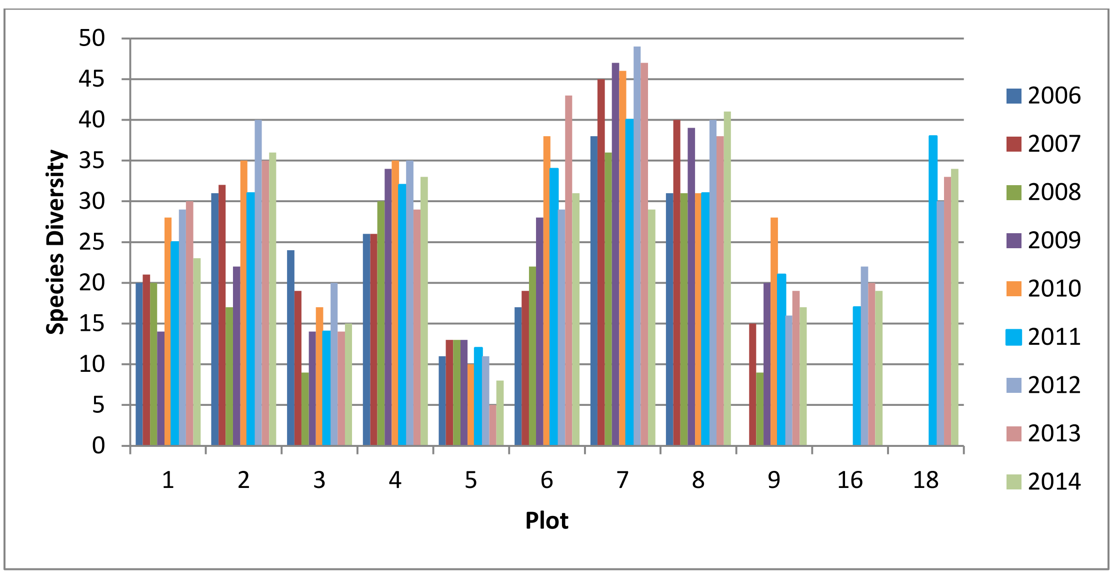

Figure 7. Change in Vegetation Diversity from 2006 to 2014

Figure 8 shows the vegetation diversity during the construction period (2010 to 2014) compared to the pre-construction average (2006 – 2009). Plots 2 and 6 both exceeded the pre-construction average positively; Plot 2 with 36 species in 2014 (25.5 pre-construction average) and Plot 6 with 31 species in 2014 (21.5 pre-construction average). Plots 5 and 7 each fell slightly below the threshold in 2014. Plot 5 is known to have a dense canopy of conifer species and as a result contains very limited herbaceous vegetation. Previous discussion in this report and in prior monitoring reports has highlighted that the establishment of an individual of a species, observed in 1 year but not the next, can greatly influence data in this plot. At this time there are no concerns relating to the low diversity noted in Plot 5 in 2014. While changes in Plot 7 diversity may be linked to the slight shifting of monitoring plots, changes may also be due to fluctuations in groundwater levels. This plot is consistently among the most diverse in the subject property with as many as 49 species recorded in 2012. This diversity is likely due to the presence of conifer forest, mixed forest, mixed swamp and a watercourse all within or near the plot. The hummocky topography provides microhabitat for a variety of wetland and upland species.

Overall, the 2014 monitoring data supports that a trend of increasing diversity is occurring throughout the site in comparison with the pre-construction average. An increase in species diversity is generally associated with a benefit to the natural environment, unless the increase is due to an introduction of a non-native, invasive species. Abundance data for non-native, invasive species does not indicate any notable increases in any one species over the course of the 9 year monitoring period. As indicated on Figure 4, the number of non-native species has generally remained steady from 2006 to 2014, often with the addition or removal of a single species from 1 year to the next. Monitoring will continue to document the presence of non-native, invasive species and will specifically assess their abundance within the plots.

To date, no stands of the aggressive invasive species Common Reed (*Phragmites australis ssp. australis*) have been observed within the site. This species has been known to establish following earth-moving works in ditches and has profound impacts on native species diversity. Annual monitoring will continue to watch for this species, in particular within SWM ponds and ditches.

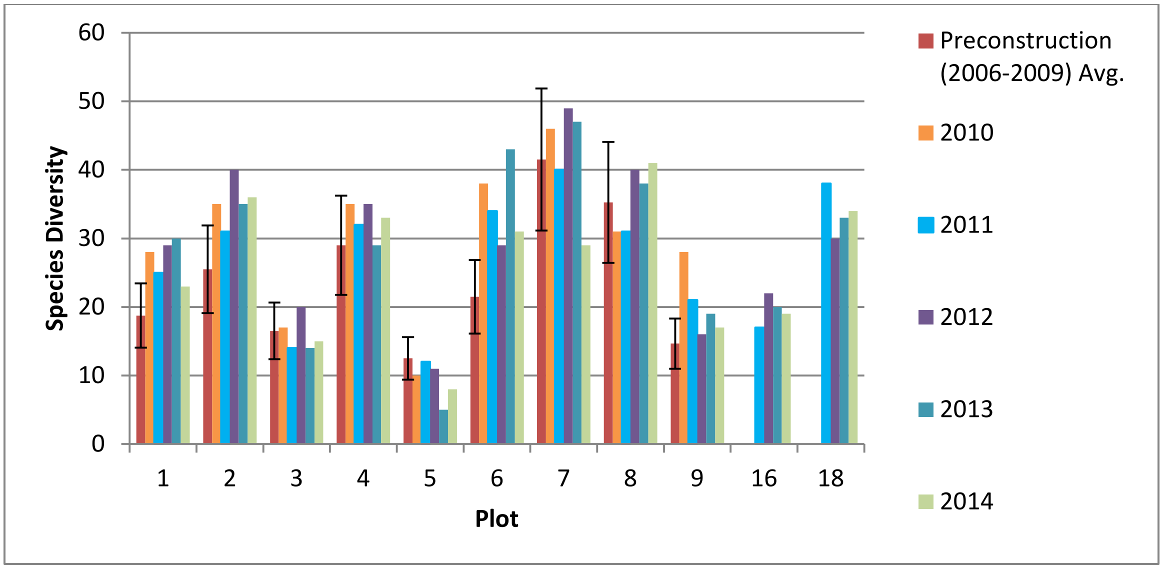

Figure 8. Change in Vegetation Diversity During 2010 to 2014 Compared to Preconstruction Average

(The preconstruction average column shows a 25% range bar)

3.2.3 Canopy Cover

The canopy cover per plot is shown on Figure 9. Plots 1, 6, and 9 have no trees and therefore canopy cover is 0%. The canopy cover in most plots has remained relatively similar over the 9 years of monitoring, with Plot 8 recovering from tree removal to the south of the plot in 2010 in preparation for the installation of the Hanlon Creek Boulevard (Road A) culvert. Plot 8 is bisected by Tributary A, with tree cover limited to the western, eastern and northern extent of the plot. Trees and shrubs were installed in the riparian area to the south of the plot in fall 2010, as detailed in the HCBP EIR Restoration Plans. It is anticipated that in time these plantings, coupled with natural succession, will begin to increase canopy cover of the plot and facilitate a return to pre-2010 conditions. The presence of EAB is also likely for some of the slight changes observed in canopy cover for plot which contain Ash trees.

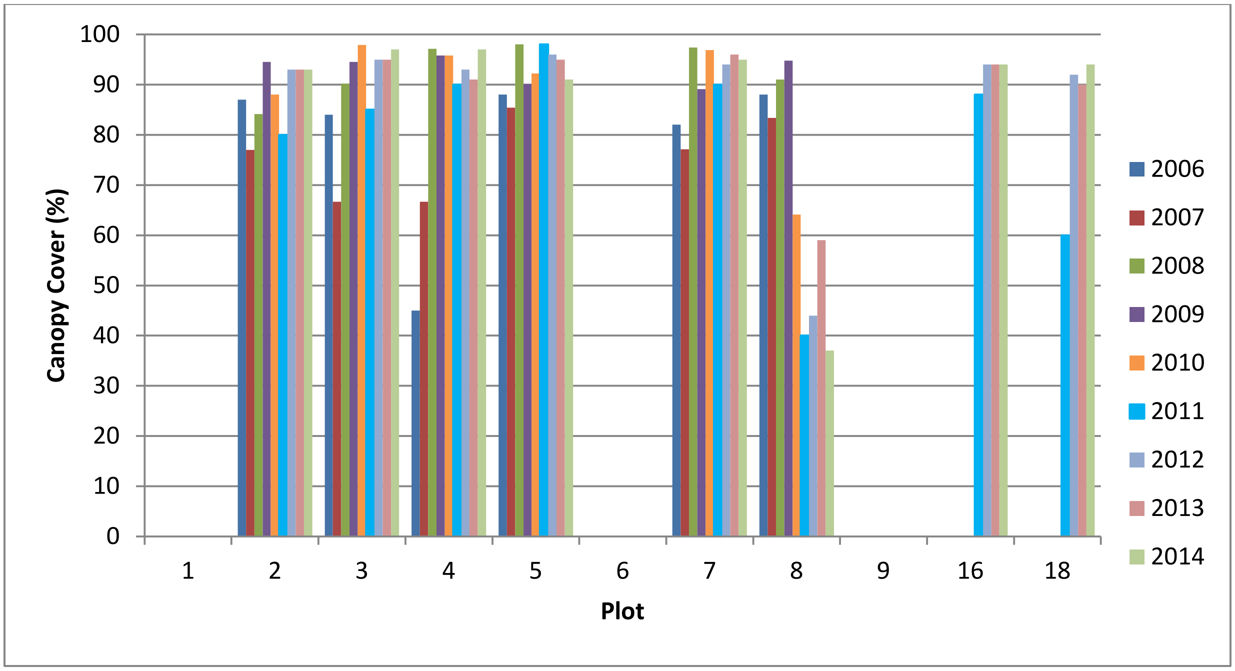

Figure 9. Change in Canopy Cover from 2006 to 2014

Figure 10 compares the canopy cover during the construction period (2010 to 2014) to the pre-construction average (2006 – 2009). A range bar shows a 25% increase and decrease from the average in canopy cover for each plot on the pre-construction column. All plots have remained within the threshold range with the exception of Plot 8 which has been well-below the threshold since the 2011 monitoring year. Given the presence of a watercourse which bisects the plot, a percentage of open tree canopy is to be expected. In 2014, restoration plantings in this area were noted to be healthy and establishing well.

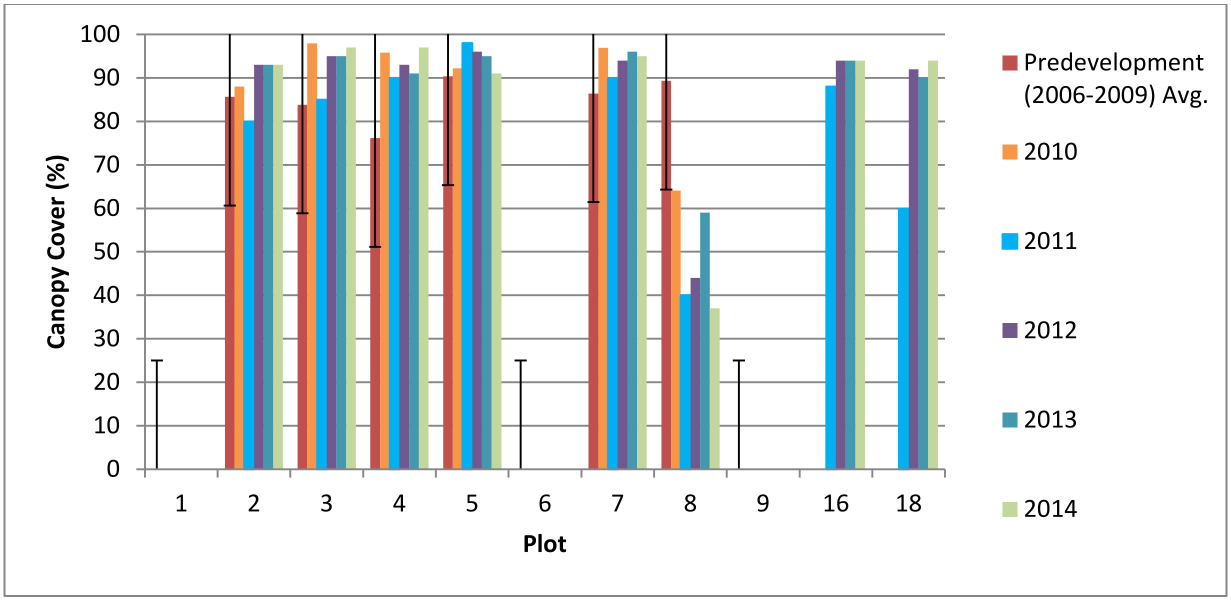

Figure 10. Change in Canopy Cover During 2010 to 2014 Compared to Preconstruction Average

(The range bar shows a 25% increase and decrease in canopy cover)

3.2.4 Vegetation Threshold Summary and Contingency Measures

The HCBP Consolidated Monitoring Program (NRSI 2010, p. 37) suggests the following measures when there is a change in vegetation or a shift in species composition beyond the established threshold:

- *"Initiate restoration efforts to enhance number of native wetland/woodland species.*
- *Provide educational material to neighbouring properties outlining importance of natural features and their protection.*
- *Provide additional signage regarding trail closures, etc.*
- *Refer to Section 6.1 Groundwater for the contingency measures associated with groundwater thresholds."*

Although several vegetation thresholds were exceeded during the 2014 monitoring season, it is not recommended that any of the above-mentioned contingency measures be carried out at this time. As explained in further detail below, a variety of causes are likely responsible for these threshold exceedances; however potentially major or irreversible changes are not being observed. Continued monitoring is recommended to ensure that vegetation communities remain intact and diverse.

Although Coefficient of Wetness (CW) is not used as a specific threshold for the vegetation monitoring, it is noteworthy that the CW values have shown a drying trend between 2011 and 2014 at Plots 16 and 18. These plots are located in close proximity to recent development (Block 9 and Block 10) and Hanlon Creek Boulevard. Groundwater levels at adjacent monitoring wells have been analyzed for temporal patterns and compared to the ground elevations. However, the drought year in 2012 is the only obvious groundwater effect. Furthermore, it appears that fluctuations in groundwater levels would have little to no effect on the soil wetness in the wetlands because their elevations have never been above the ground surface of the wetlands. Groundwater levels in the vicinity of Plots 16 and 18 do not show a trend that matches the declining trend in CW values. Monitoring of vegetation and groundwater should continue at these plots in order to determine whether there is a relationship between groundwater and the CW values.

Herbaceous Cover

Herbaceous cover exceeded the threshold positively in Plots 2 and 8 which is seen as a positive trend for these plots. Plots 1 and 3 both exceeded the lower reach of the threshold in 2014.

In Plot 1, the presence of shallow water within the plot during the July vegetation monitoring date reduced the amount of herbaceous cover from recent years. This exceedance is not seen as a negative impact overall as the vegetation community is adapted to hydric soils and standing water provides a number of benefits to wildlife including anurans, mammals and birds. The western fringe of Plot 1 accounts for most of the herbaceous vegetation within the plot as it is a transition between meadow and the willow thicket swamp. Within the swamp itself most herbaceous vegetation is found growing on the hummocks of willow clumps or aquatic species such as Lesser Duckweed (*Lemna minor*).

While increases in herbaceous species in Plot 3 (7.2% between 2013 and 2014) reflect a positive change in recent years, the 16.3% cover in 2014 is still well below the pre-construction average of 57.83%. Should the site receive abundant precipitation during the spring of 2015, vegetation monitoring may find that herbaceous cover continues to build on the 2014 figures. It should also be considered that the mortality of Ostrich Fern during the driest monitoring years would require time for the population to rebound (assuming conditions are suitable for the species) to pre-construction numbers.

Species Diversity

Species diversity positively exceeded the pre-construction threshold in both Plots 2 and 6. Given that these increases were not based on the addition of aggressive non-native species to the plots, these changes are considered positive. Plots 5 and 7 both fell below the threshold in 2014. With consistently low species diversity, the threshold for Plot 5 is based on a small number of species and is thus easily exceeded. Had the 8 species observed in 2014 monitoring been raised to 10, the plot would have been within the lower reach of the threshold. As a dense conifer stand, it is not anticipated that species diversity will change drastically within this plot in the near future.

Plot 7 was just below the lower reach of the threshold in 2014 but still remains one of the most diverse plots within the subject property. Some discrepancy has been attributed to the potential shifting of the monitoring plot; the hummocky terrain means that a shift of several degrees in either direction for the 5, 1x1, sub-plots can include or exclude several species from the plot list. Changes in groundwater levels may be responsible for the disappearance of wetland species such as Marsh Skullcap (*Scutellaria galericulata*), Clearweed (*Pilea pumila*) and Spotted Jewelweed (*Impatiens capensis*), none of which were ever widespread or abundant within the plot.

Ongoing monitoring will continue to assess the increase or decrease in species diversity including an analysis of non-native species within each plot. Similar to previous monitoring years, non-native species were recorded in all plots in 2013, except Plot 5.

Canopy Cover

Plot 8 remains the only plot which exceeded the canopy cover threshold. As reported in the 2011 HCBP Consolidated Monitoring Report (NRSI 2012a), canopy cover has been reduced in Plot 8, but the area of impact, adjacent to the plot has been restored through native plantings according to the HCBP EIR Restoration Plans. These plantings are being monitored for success and will increase shading to Tributary A that bisects Plot 8 as they mature.

3.3 Breeding Bird Surveys

A total of 42 species of birds were observed during the breeding bird monitoring that was conducted in 2014 (Appendix VIII). Including those species which were noted outside of point counts or incidentally during other surveys, a total of 51 bird species were documented within the study area in 2014 (Appendix IX). Table 5 summarizes the number of birds observed during breeding bird point count surveys under each breeding evidence code.

Table 5. Breeding Bird Evidence

Breeding Evidence	Number of Species								
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Possible	30	12	20	21	20	21	25	21	15
Probable	11	15	14	20	18	22	21	24	23
Confirmed	0	11	2	4	2	2	4	3	2
None*	0	8	4	0	5	2	1	2	2
TOTAL	**41**	**46**	**40**	**45**	**46**	**47**	**51**	**50**	**42**

*Species observed with no breeding evidence (i.e. flying overhead)

The most abundant species observed during 2014 surveys were Red-winged Blackbird (*Agelaius phoeniceus*), and American Robin (*Turdus migratorius*), both with 11% of the observations during breeding bird point counts. These were followed by Song Sparrow (*Melospiza melodia*) at 9% and American Goldfinch (*Spinus tristis*) at 5%. These species are consistently the most abundant within the point counts largely due to the presence of suitable habitat and the large populations of these species within Southern Ontario. Figure 11 represents the 9 most abundant species observed in 2014, with all other birds observed less frequently lumped together in 'other'.

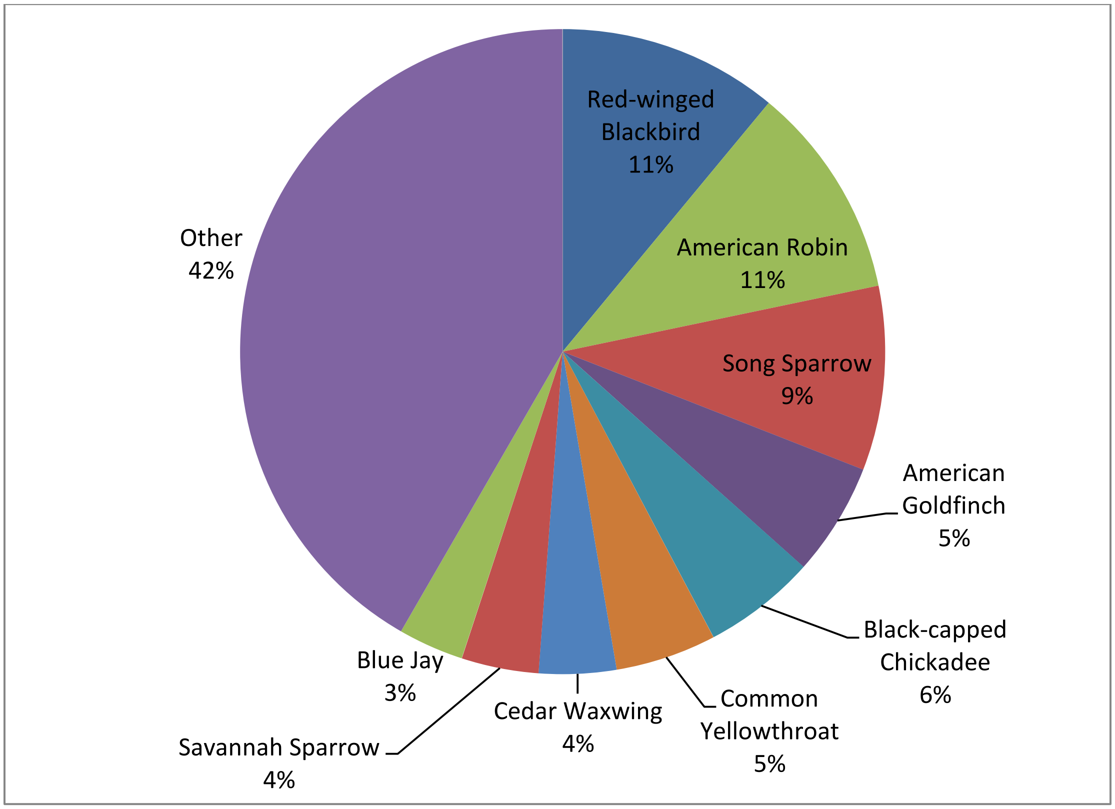

Figure 11. Most Abundant Bird Species Observed in 2014

3.3.1 Breeding Bird Species Diversity

Figure 12 graphs the species diversity of breeding birds at each plot since monitoring began in 2006. A total of 42 bird species were recorded during breeding bird surveys in 2014. In 2013, 50 species were recorded which stood as the highest diversity to date; the low tally for diversity of 40 species was documented in 2008 (pre-construction monitoring year). Including the observation of incidental bird species throughout 2014, the overall bird species diversity was 51 species.

Plot 11 had been identified in the 2012 monitoring report (NRSI 2013) as showing a consistent decrease in species diversity between the 2009 and 2012 monitoring years. Diversity rebounded substantially to 22 species in 2013 while 17 species were recorded in 2014 at the point count station. The very limited amount of traffic or construction work immediately north of Plot 11 in 2013 and 2014, coupled with the establishment of weeds and cool season grasses within the recently graded area may be responsible for the positive trend in species diversity.

Since monitoring of Plot 16 began in 2011, species diversity has fluctuated from 17 species recorded in 2011 to only 5 in 2014. Construction has been ongoing to the east of this monitoring station for several years with the build out of Block 9 and 10. As noted in the 2013 monitoring report, the on-going construction of buildings in the vicinity of Plot 16 will likely maintain the level of human disturbance in the area for several more years. It is anticipated that once construction has subsided within the immediate area surrounding Plot 16, bird diversity may increase with lower noise levels and the establishment of edge plantings. The naturalizing meadow to the south is likely to contribute to increases in species diversity in the coming years.

Within Phase 3, Plot 19 and Plot 20 showed a decrease in bird species diversity as documented in 2012 and 2013; however numbers were still notably higher than in 2011. Given that the composition and structure of the successional old field habitat is likely improving and becoming more suitable to open country bird species year after year, the lower numbers observed in 2014 may be attributed to natural fluctuation in bird diversity. Song Sparrow and Savannah Sparrow (*Passerculus sandwichensis*) remained relatively abundant within the open country plots in Phase 3; both showing probable breeding evidence. In Plot 20, Bobolink (*Dolichonyx oryzivorus*) and Eastern Meadowlark (*Sturnella magna*) were noted showing probable and possible breeding evidence respectively. As many as 6 Bobolink were documented within Plot 20 during the June 25 survey, while 2 Eastern Meadowlark were documented during the June 13 survey. Both species are listed as Threatened provincially and nationally (MNRF 2015b, COSEWIC 2015) and have been recorded in Plot 20 in 2010, 2011 and 2013.

Barn Swallows (*Hirundo rustica*) were observed as fly-overs in the vicinity of Plot 20 on both survey dates. Suitable nesting habitat for this species is present at the abandoned farmhouse within Phase 3. This species is also listed as Threatened provincially and nationally (MNRF 2015b, COSEWIC 2015).

In general, the diversity of bird species at each plot in 2014 was similar to those numbers documented between 2006 and 2011, with 2012 and 2013 appearing as exceptional years of high diversity across the study area.

In 2014, 2 bird species new to the site were recorded either during breeding bird surveys or incidentally. These species included Green Heron (*Butorides virescens*) and Solitary Sandpiper (*Tringa solitaria*). Green Heron was recorded as a fly-over and did not exhibit any signs of breeding. Solitary Sandpiper was documented incidentally as showing probable breeding evidence near Plot 7. While mud flats and fringes associated with SWM ponds on site may provide suitable foraging habitat for this species, the known breeding range in Ontario exists within boreal forests of the north (Moskoff 2011, BSC 2015). It is likely that this species was a migrant and did not breed on site in 2014. Another species of note, the regionally significant Black-billed Cuckoo (*Coccyzus erythropthalmus*) was documented as showing breeding evidence (probable) within the subject property for the first time in 2014; it had been observed in previous years but not showing any signs of breeding.

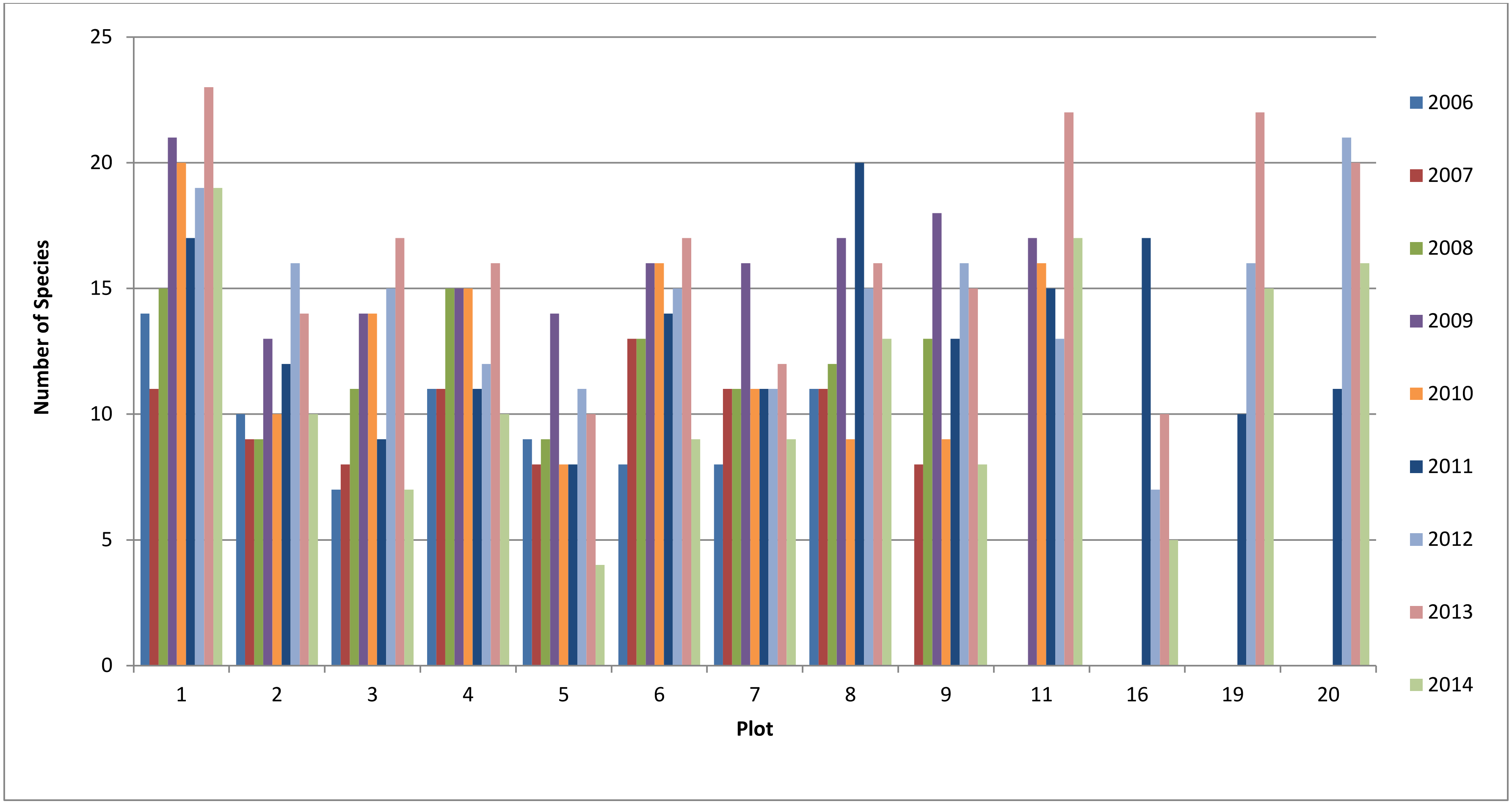

Figure 12. Breeding Bird Species Diversity 2006 – 2014

3.3.2 Breeding Bird Abundance

The breeding bird abundance (the number of individual birds) since 2006 is shown on Figure 13. In general the 2014 abundance reflects the overall average since monitoring began in 2006. Similar to species diversity, breeding bird abundance showed a notable spike during the 2012 and 2013 monitoring years and 2014 data reflects abundance data observed between 2006 and 2011. Those species which have tended to comprise much of the abundance value for each plot including Red-winged Blackbird, American Goldfinch, Song Sparrow, Black-capped Chickadee and American Robin continue to comprise the bulk of individuals observed. Spikes in bird abundance have been observed in past monitoring years due to large flocks of a single species which have included Red-winged Blackbirds in Plot 6 in 2006 and Canada Goose (*Branta canadensis*) in Plot 9 in 2007.

Plots 1 and Plot 6 continue to have among the highest bird abundance (51 and 33 respectively); however Plot 20 has also shown high abundance since 2012. These plots are likely to yield higher bird abundance due to a combination of treed and open upland and wetland habitats present within the immediate survey area. Those plots which consistently show the lowest bird abundance, particularly Plot 5 are situated well within wooded features and are thus less likely to have species that prefer edge or open country habitat. Comprised largely of White Cedar and lacking understorey or groundcover vegetation, only 8 birds were documented in Plot 5 during breeding bird surveys in 2014.

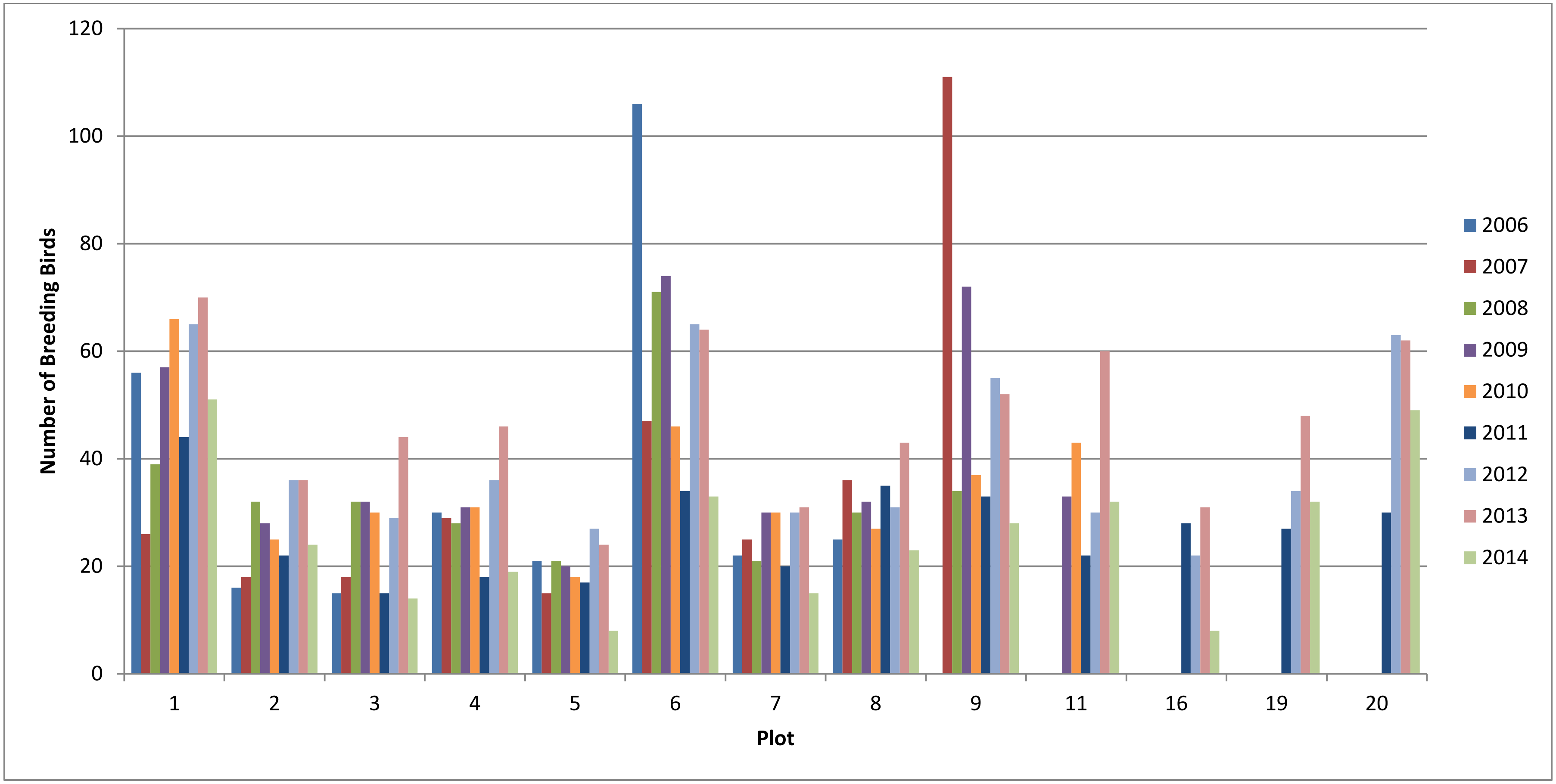

Figure 13. Breeding Bird Abundance 2006 - 2014

3.3.3 Significant Bird Species

NRSI observed 3 species that are considered Threatened federally and provincially (COSEWIC 2015, MNRF 2015b): Barn Swallow, Bobolink, and Eastern Meadowlark. Bobolink was listed as Threatened by COSEWIC and COSSARRO in 2010, while Barn Swallow and Eastern Meadowlark were up-listed in 2011. Bobolink requires large, open expansive grasslands (>50ha) with dense ground cover; hayfields, meadows or fallow fields; marshes (OMNR 2000). This species has been observed each monitoring year with probable breeding evidence documented in 2010 and 2012 through 2014. In 2014, Bobolinks were observed only within Plot 20.

Barn Swallows are found in farmlands and rural areas, and generally use buildings (such as barns) or other man-made structures for nesting. They are often found foraging in open country near water (Brown and Bomberger-Brown 1999, OMNR 2000a). In 2014, this species was recorded as a fly-over for Plots 9, 19 and 20. The Crawley farmhouse which exists near Plot 20 may provide suitable nesting habitat for Barn Swallow; however, no breeding evidence was observed at Plot 20 or within the subject property in 2014. Barn Swallow may also be nesting outside of the subject property in barns along Forestell Road or Downey Road and utilizing the subject property for foraging habitat.

Eastern Meadowlark requires grassy meadows, farmland, pastures or hayfields at least 10ha in size (OMNR 2000). Suitable habitat for these open country birds is found within the southwest portion of the subject property (Phase 3) as well as within the retained open meadow habitat associated with Plot 19 (Map 1). This species was recorded as showing possible breeding evidence in 2014 and has been recorded showing possible or probable breeding evidence on site every year since 2007. As noted in previous monitoring reports, the establishment of old field meadow throughout Phase 3 is providing suitable breeding habitat for open country breeding bird species.

Eastern Wood-Pewee (*Contopus virens*) is listed as Special Concern federally and provincially (COSEWIC 2015, MNRF 2015b). Eastern Wood-Pewee prefers open forest (deciduous, coniferous or mixed) often predominated by oak with little understory or forest clearings, edges, farm woodlots or parks (OMNR 2000). A single singing male was observed at Plots 2, 11 and 19 during the June 7, 2014 survey with a single singing male at Plots 2 and 19 during the second visit denoting probable breeding evidence. Given that a single bird was observed at 3 plots in close proximity, it is possible that the same bird was observed / heard at multiple locations and on multiple survey dates.

A total of 15 bird species were observed which are considered significant within the City of Guelph (Dougan & Associates 2009). Of these 15 species, 1 showed confirmed breeding evidence; Belted Kingfisher (*Megaceryle alcyon*) at Plot 8. A total of 7 species showed probable breeding evidence, including Baltimore Oriole (*Icterus galbula*), Bobolink, Savannah Sparrow (*Passerculus sandwichensis*), Rose-breasted Grosbeak (*Pheucticus ludovicianus*), American Redstart (*Setophaga ruticilla*), Willow Flycatcher (*Empidonax traillii*) and Black-billed Cuckoo. Additionally, 3 species showed possible breeding evidence and 4 did not show any breeding evidence (i.e. flying over habitat). Significant species within Wellington County which had not been recorded within the subject property previously included Green Heron (*Butorides virescens*) and Barred Owl (*Strix varia*).

Table 6 lists the nationally, provincially, and locally significant bird species that were observed by NRSI in 2014.

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Table 6. Significant Bird Species Observed in 2014

Common Name	Scientific Name	SRANK[1]	COSEWIC[2]	COSSARO[3]	Local Status[4]	2014 Breeding Evidence
American Redstart	*Setophaga ruticilla*	S5B			√*	PR
Baltimore Oriole	*Icterus galbula*	S4B			√*	PR
Bank Swallow	*Riparia riparia*	S4B			√*[1]	PO
Barn Swallow	*Hirundo rustica*	S4B	T	THR		X
Barred Owl	*Strix varia*	S5			√	X
Belted Kingfisher	*Megaceryle alcyon*	S4B			√	CO
Black-billed Cuckoo	*Coccyzus erythropthalmus*	S5B			√*	PR
Bobolink	*Dolichonyx oryzivorus*	S4B	T	THR	√*	PR
Eastern Kingbird	*Tyrannus tyrannus*	S4B			√*	PO
Eastern Meadowlark	*Sturnella magna*	S4B	T	THR	√*	PO
Eastern Wood-Pewee	*Contopus virens*	S4B	SC	SC		PR
Grasshopper Sparrow	*Ammodramus savannarum*	S4B			√	PO
Green Heron	*Butorides virescens*	S4B			**	X
Northern Flicker	*Colaptes auratus*	S4B			√*	PO
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	S4B			√*	PR
Savannah Sparrow	*Passerculus sandwichensis*	S4B			√*	PR
Turkey Vulture	*Cathartes aura*	S5B			√	X
Willow Flycatcher	*Empidonax traillii*	S5B			√	PR

[1]MNRF 2015a; [2]COSEWIC 2015; [3]MNRF 2015b; [4]Dougan and Associates 2009

LEGEND
SRANK
S4 Apparently Secure
S5 Secure
B   Breeding Population
COSEWIC/COSSARO
T/THR   Threatened
SC/SC Special Concern
Local Status (Wellington)
√   Significant and rare
√* Significant but not rare
** Only habitats that support or have recently supported nest sites are considered significant
Breeding Evidence Codes
PO Possible
PR Probable
X   No breeding evidence

3.4 Bird Threshold Assessment

3.4.1 Breeding Bird Species Diversity

The threshold for breeding birds established in the HCBP Consolidated Monitoring Program (NRSI 2010) is a change of 25% in species diversity (number of different species). A decrease in species diversity beyond the threshold is considered to represent a potential concern. An increase beyond the threshold is considered to be positive and does not warrant that any remedial action be taken. Figure 12 graphs the species diversity for breeding birds since monitoring began in 2006. Figure 14 compares the 2010 to 2014 breeding bird species diversity to the preconstruction (2006-2009) average species diversity. In 2014, 4 plots were below the threshold; Plots 3, 5, 6 and 9. Plots 16, 19 and 20 also showed decreases from 2013 values.

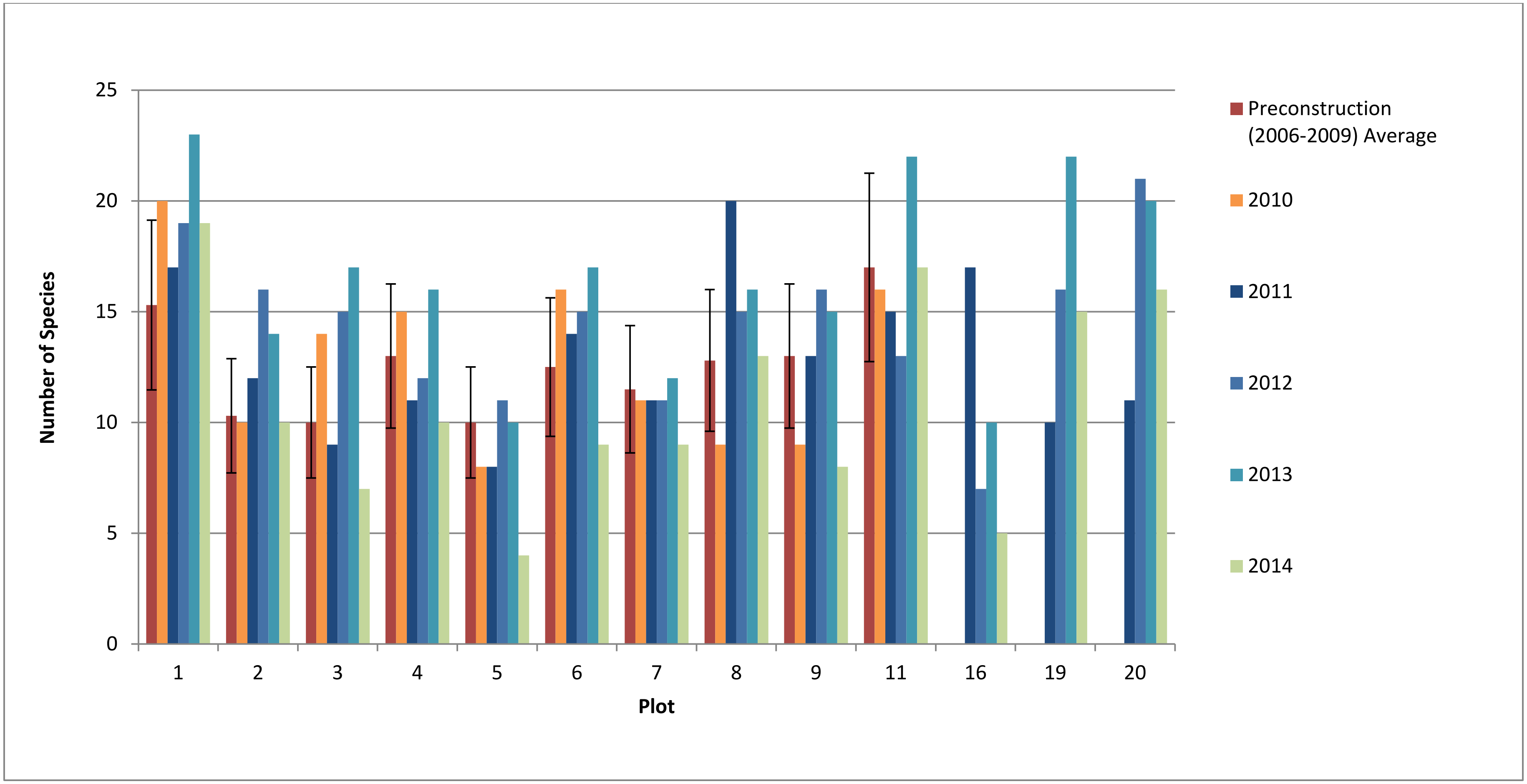

Figure 14. Breeding Bird Species Diversity During 2010 to 2014 Compared to Preconstruction Average

(The range bar shows a 25% change in the number of breeding bird species)

3.4.2 Breeding Bird Abundance

The threshold for breeding birds established in the HCBP 2010 Consolidated Monitoring Report (NRSI 2010) is a change of 25% in breeding bird abundance (the number of individual birds). Figure 13 graphs breeding bird abundance since 2006. Bird abundance in 2014 reflected the lower diversity with lower abundance recorded across the study area.

Figure 15 compares 2010 to 2014 during construction data with breeding bird abundance from the preconstruction years (2006 – 2009). The preconstruction average column shows the 25% range bar, indicating the threshold. Plots 3, 4, 5, 6, 7 and 9 were all below the threshold in 2014.

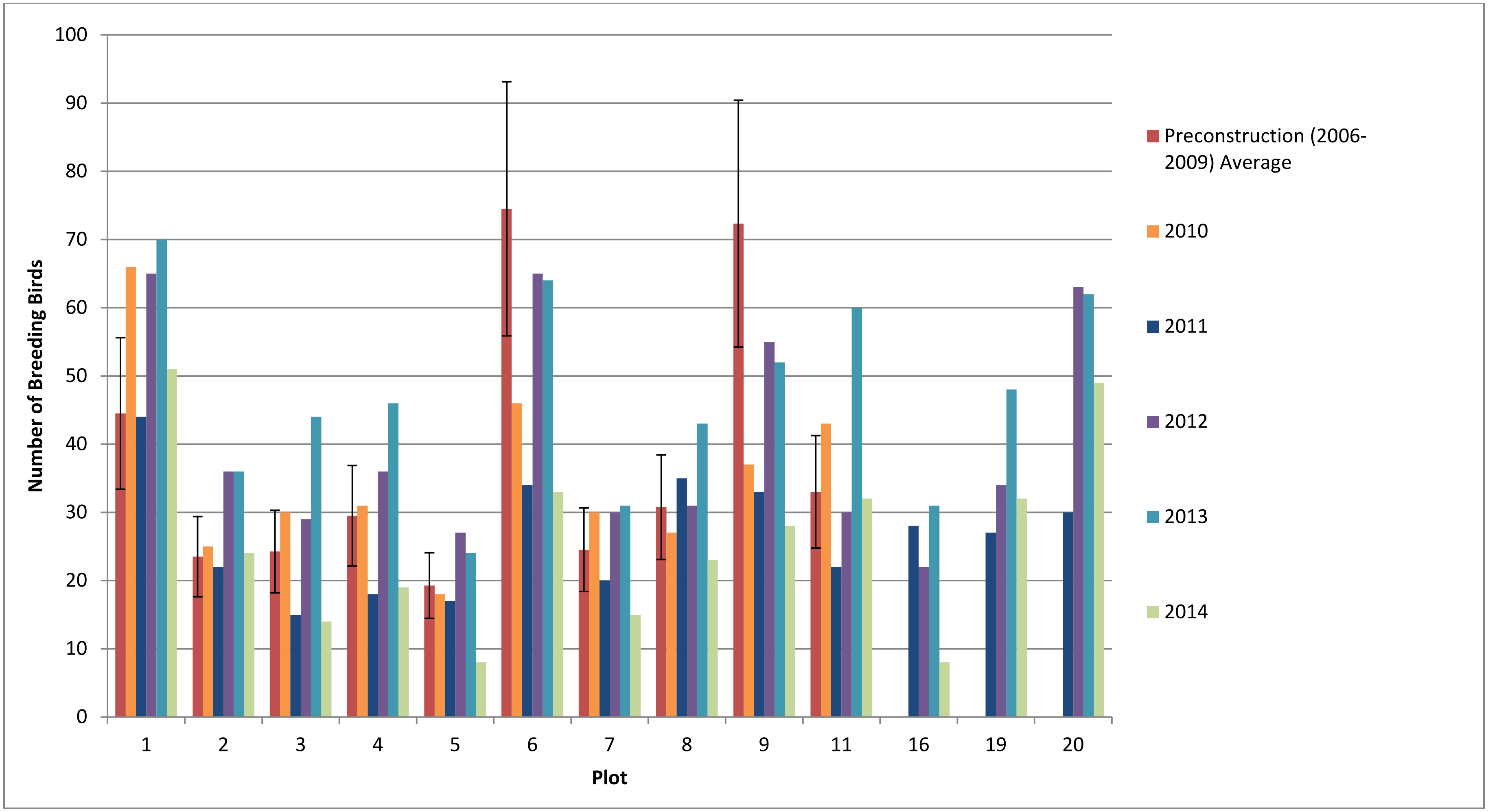

Figure 15. Breeding Bird Abundance 2006 - 2014

(The range bar shows a 25% change in the number of breeding birds)

3.4.3 Bird Threshold Summary and Contingency Measures

The HCBP Consolidated Monitoring Program (NRSI 2010, p. 39) suggests the following measures when bird species decline beyond the established threshold:

- *"Assess success of naturalization/restoration plantings. If plantings are not establishing, increase buffer/natural area plantings.*
- *Assess status of restoration plantings (e.g. if shrub and tree species are beginning to proliferate in open meadow areas, return naturalized area to intended habitat type).*
- *Increase buffer plantings or alter if necessary.*
- *Provide educational material to neighbouring properties outlining importance of natural features, wildlife and their protection.*
- *Provide additional signage regarding trail closures, etc."*

In 2014, bird species diversity and abundance were both notably lower in a number of plots. Negative threshold exceedances for bird species diversity occurred at Plots 3, 5, 6 and 9, with Plot 16, 19 and 20 all lower than 2013 figures. Similarly, the threshold for bird abundance was negatively exceeded in Plots 3, 4, 5, 6, 7 and 9 with Plot 16, 19 and 20 all showing lower figures than the previous year. The thresholds that were exceeded are summarized as follows along with recommendations for continued monitoring.

Breeding Bird Species Diversity

Breeding bird species diversity was below the threshold at 4 plots in 2014 with the remaining plots within the threshold. No plots positively exceeded the threshold in 2014. Data indicates that species diversity in 2013, and 2012, to some extent, were exceptionally high in comparison to previous years which raised the 25% threshold notably. In 2014, Plots 3, 6 and 9 were near the lower reach of the threshold, while Plot 5 was well below the threshold.

It is noted that Plots 3 and 5 are located in areas that are well-removed from active construction and it is inferred that trends in these plots are the result of natural fluctuations. Breeding bird survey dates have remained essentially the same over the monitoring period as well as the habitats within these plots. Reductions in the extent of agricultural land use in Phase 3 have resulted in fallow fields in the vicinity of Plot 3 and

9 which should increase species diversity. Plot 5 is situated within an area of low vegetation diversity with a uniform canopy and minimal understorey, shrub layer or herbaceous layer. Given the simplicity of the habitat, this area is not likely to support a diversity of bird species.

Overall, the 2014 data strongly reflects a year of lower-than-average bird diversity. Temporary impacts relating to nearby development, such as at Plot 16, as well as annual fluctuations in bird presence at each plot are to be expected. Continued monitoring will help to inform long-term trends.

Breeding Bird Abundance

Reflective of the reduction in species diversity in 2014, breeding bird abundance was also notably lower than average for a number of plots in 2014. As mentioned in previous monitoring reports, observations of flocks can have a notable impact on bird abundance figures. The threshold set within Plots 6 and 9 for pre-construction (2006-2009) both include very large numbers of Red-winged Blackbird or Canada Geese which inflated the threshold substantially. In 2014, no more than 8 individuals of a species were observed at a given plot (many tallies were 6 or lower). As species diversity was lower in 2014, it is expected that abundance would be lower. As both 2012 and 2013 constitute years of high bird abundance, and the presence of flocks within pre-construction threshold calculations, 2014 data is generally on average with the during-construction data set despite the 6 threshold exceedances which were documented.

Monitoring should continue to assess breeding bird abundance to determine if bird abundance is being maintained across the site and within the different vegetation communities.

3.5 Amphibian Surveys

3.5.1 Call Count Surveys

Five amphibian species were recorded during evening call count surveys in 2014; Spring Peeper (*Pseudacris crucifer crucifer*), Wood Frog (*Lithobates sylvatica*), Northern Leopard Frog (*Rana pipiens*), Green Frog (*Rana clamitans melanota*) and Gray Treefrog (*Hyla versicolor*). Since 2006, the number of species recorded during the calling anuran surveys has fluctuated. The 5 amphibian species recorded calling in 2014 is above average among species numbers recorded in previous years.

Amphibian species abundance is shown in Table 7. These fluctuations may be correlated with changing weather conditions from year to year, such as spring precipitation and night-time air temperatures, which strongly influence amphibian breeding success.

It should be noted that although 2006 surveys studied 6 amphibian monitoring stations, additional stations were added in subsequent years bringing the total number of stations monitored since 2011 to 11. Appendix X provides a list of amphibian species and their associated call count information observed by NRSI biologists during surveys from 2006 to 2014.

Table 7. Number of Calling Anuran Species Recorded During Call Count Surveys

Year	# of Species
2006	0
2007	5
2008	4
2009	6
2010	3
2011	4
2012	3
2013	4
2014	5

In order to compare species abundance over time and between stations, the maximum call code is used. The maximum call code is used to provide an estimate of abundance, as estimating numbers of individuals is not accurate. The three call codes as per the Marsh Monitoring Protocol (BSC 2008) are:

Call Level 1. Calls can be counted; not simultaneous
Call Level 2. Some simultaneous calls; yet distinguishable
Call Level 3. Calls not distinguishable; overlapping (i.e. “full chorus”)

By comparing the number of stations at which a species was observed, and the maximum call code over time, increases or decreases in species abundance can be determined (see Tables 8 and 9). The following is a brief discussion of trends observed by species:

Spring Peeper

- most abundant anuran in 2014 with a full chorus (many individuals; too many to count accurately) recorded at 2 stations (Plots 1 and 9),
- recorded for the first time in Plots 14 and 17 in 2014,
- consistent with previous years, Spring Peeper was also the most widely distributed anuran in 2014. They were recorded from 8 of the 16 anuran monitoring stations.

Green Frog

- documented calling in low numbers at Plot 4 and Plot 15,.
- estimated total of 7 calling individuals, all documented on the June 9 survey,
- documented sporadically between 2007 and 2014 in low numbers.

Gray Treefrog

- was the second most widely distributed species in 2014 at 6 of 16 stations,
- recorded in high numbers at Plot 1 in 2013 and 2014. Plot 1 exists within Willow thicket swamp and is regularly subject to seasonal flooding.

Wood Frog

- notably low numbers of Wood Frog calling in 2014 with a single individual at Plot 1 and Plot 15,
- abundance for this species remains highly variable with a distinct pattern of high numbers 1 year followed by low numbers the next year.

Northern Leopard Frog

- a single frog was documented during calling anuran surveys at Plot 4,
- throughout the monitoring period (2006-2014) this species has been limited in numbers and distribution throughout the study area.

Other Species

- no Pickerel Frog (*Rana palustris*) or Western Chorus Frog (*Pseudacris triseriata*) were observed in 2014, either during call counts or incidentally.
- both of these species have been recorded intermittently within the subject property in previous years, with a call code of 1 or 2 and in low numbers.

With regard to the plots:

- 12 of the 16 plots recorded calling anuran species in 2014,
- in 2014, Plots 1 and 16 all recorded 3 species of anuran,
- no calling anurans were recorded in 2014 at Plots 7, 8, 10 and 13. These plots generally lack standing water and do not provided ideal anuran breeding habitat.

Table 8. Maximum Call Code Recorded

(insert pdf from excel file)

Table 9. Number of Individual Anurans Recorded During Call Count Surveys

(insert pdf from excel file)

3.5.2 Amphibian Call Survey Site Conditions

Amphibians breed in several types of wetland habitat. All require the presence of water for some duration of the spring. Some species, such as Spring Peeper, Western Chorus Frog, and Wood Frog, take advantage of temporary, seasonal pools created by spring rains and melting snow. The temporary pools dry up by mid to late summer, at which time the tadpoles have metamorphosed into adults and moved to upland habitats. Some species of anurans, such as Leopard Frog, Green Frog, and Bullfrog (*Rana catesbeiana*), require semi-permanent to permanent water bodies in order for the tadpoles to develop into adults, which can take up to 2 years.

Many of the point count locations exhibited shallow standing water for the first 2 surveys with standing water becoming limited to several locations by the June survey date. Permanent standing water is present within the recently constructed SWM pond in Phase 2 (SWM Pond 4) and SWM Ponds 1 and 2 in Phase 1 (Map 2), as well as the 2 manicured ponds within the residential property north of Laird Road. Incidental observations of amphibians continue to be recorded within the SWM ponds and the maturation of buffer plantings surrounding these features will help to improve these habitats and increase the presence of frog and toad species, in particular American Toad and Spring Peeper.

Weather on the first visit in 2014 (April 29), was 8°C, dropping down to 5°C by the end of the evening. Skies were partly cloudy with a gentle breeze and no precipitation. The second visit, May 21, had no precipitation, overcast skies, with an air temperature of 22°C dropping to 15°C, with a slight breeze. During the final visit on June 9, air temperature was 20°C dropping to 17°C, with overcast skies, no precipitation and no wind.

Water temperatures ranged from 5.0 to 8.4°C on the first visit. During the second visit, water temperatures ranged from 8.5 to 18.8°C. Water temperatures within the 4 plots containing water on the third visit (Plots 1, 2, 4 and 8) ranged from 10.4°C to 17.1°C. While some of the monitoring stations had no water present by the second and third survey, suitable conditions were more widespread in 2014 than in years such as 2012 when pooled water was very limited across the site. Temperatures throughout the spring of 2014 were also favourable to anuran breeding with no notable cold snaps and generally mild temperatures between April and June.

Anurans are known to prefer habitats that are pH neutral (pH 7) (Audubon International, 2000). When pH values decrease, becoming acidic, or increase, becoming alkaline, it can impact their survival. Seburn and Seburn (1998) stated that the northern leopard frog breeds successfully at a pH range of 8.5-9.5 and that fertilization of eggs is reduced at a pH of less than 6.5.

Chemical processes such as photosynthesis and drying out that occur daily and throughout the breeding season result in fluctuations of water pH and other water chemistry values (Wetzel 1983). A study of 180 ponds across southwestern Ontario found that pH averaged 8.3 +/-0.05 with a range of 7.2-10.2 (Hecnar and M'Closkey 1996). According to this study, ponds in southwestern Ontario, are generally alkaline, hard, and well buffered with high pH values. Hecnar and M'Closkey (1996) did not find any correlation between amphibian species richness and water chemistry. Several studies have found that amphibian species richness is not related to water chemistry (pH, conductivity, and hardness) (Hecnar and M'Closkey 1996). The presence or absence of anuran species is more commonly related to hydroperiod and the presence of predatory fish.

pH values recorded during the April and May surveys ranged from 7.4 to 8.3 with most in the range of 7.6-7.8. This range aligns with average pH values recorded in previous monitoring years. Similar to previous years, pH values in 2014 were based upon all plots which contained water and it should be noted that a number of plots were dry on one or more of the calling amphibian survey dates. The pH values found during the monitoring period are within the normal range for southern Ontario. The recorded pH levels have not been recognized as having harmful effects on the presence of amphibian species.

3.6 Amphibian Threshold Assessment

The thresholds for amphibians established in the HCBP Consolidated Monitoring Program (NRSI 2010) and the HCBP 2011 Consolidated Monitoring Report (NRSI

2012a) are a decrease in species diversity (number of species) by more than 2 species and a significant change in species abundance, measured by a decrease in 2 call codes. Such changes may constitute a concern.

3.6.1 Amphibian Species Diversity

Figure 16 graphs the species diversity for anurans since 2006. In 2014, no plots showed a reduction in species by more than 2 species between 2013 and 2014 or between the pre-construction average and 2014. Plots 6 and 16 showed a reduction of 2 species between 2013 and 2014; however this is considered to be within the threshold limits. In 2014, 5 plots showed an increase in anuran species diversity over 2013 data.

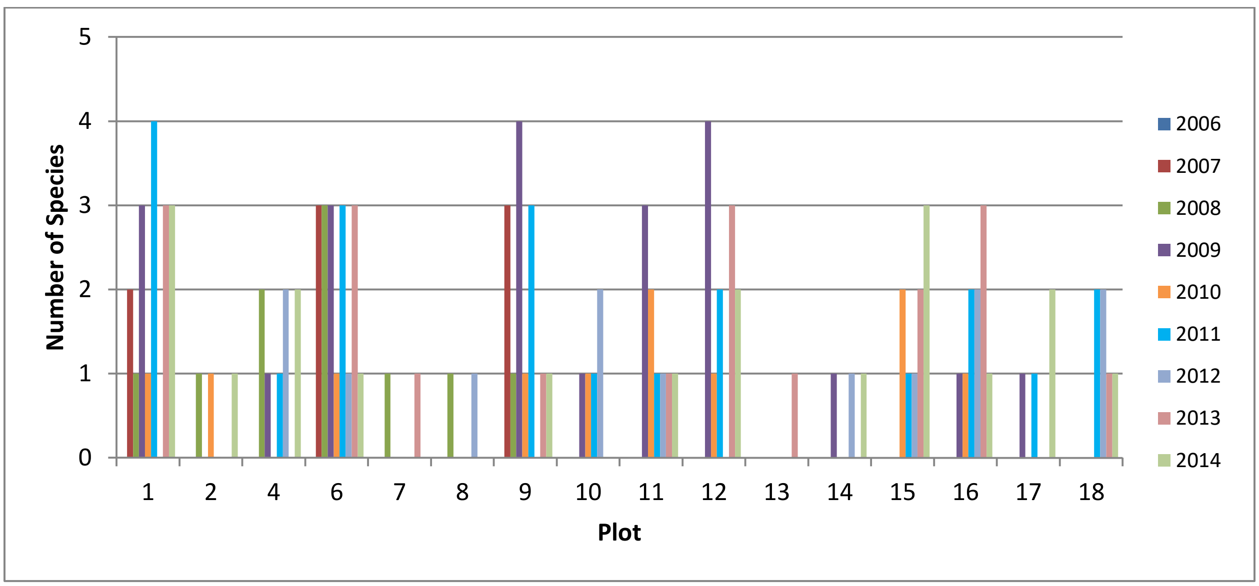

Figure 16. Amphibian Species Diversity 2006 - 2014

3.6.2 Amphibian Species Abundance

A drop in 2 calling codes was established as the threshold in the HCBP Consolidated Monitoring Program (NRSI 2010). Several of these drops were observed in 2014 including:

- Gray Tree Frog in Plots 7 and 16 – no individuals recorded in 2014, down from a call code 2 recorded at each of these plots in 2013,

- Spring Peeper in Plot 6 – no individuals recorded in 2014, down from call code 2 recorded in 2013,
- Wood Frog in Plots 6 and 16 – no individuals recorded in 2014, down from a full chorus of 3 in each plot in 2013,

It should be noted that the overall abundance of both Gray Tree Frog and Spring Peeper across the site reflects data gathered in 2013 and abundance for both has remained relatively consistent since 2006. As noted in previous monitoring reports, the use of SWM ponds by Spring Peepers, as well as American Toads, has increased notably since their creation. The continued establishment of riparian and aquatic vegetation within SWM ponds will likely continue to provide suitable foraging and breeding habitat for some anuran species.

Seemingly subject to alternating years of high abundance followed by low abundance, Wood Frog numbers were low in 2014, similar to data collected in 2012, 2010, 2008 and 2006. Research shows that prolonged periods of dry weather may reduce adult breeding populations either directly or through reduced juvenile recruitment and a shortened larval period (Berven 1990).

The remaining identified species, Green Frog, Northern Leopard Frog, Pickerel Frog and Western Chorus Frog have all been observed intermittently within the subject property dating back to the 2007 monitoring year. Generally these species have been observed in low numbers at a call code of 1 or 2. It is likely that these species have always existed in low numbers within the property and are subject to natural population fluctuations.

As noted above, 2 of the 6 species abundance decreases which surpassed the threshold occurred in Plot 16 which was noted previously for decreases in herbaceous vegetation and bird species diversity. Previous monitoring reports have noted the drier conditions being observed at the plot in recent years; during 2014 calling anuran surveys, water was present throughout April and May but had dried up by June. All 3 survey dates note calling anurans from the adjacent SWM pond or the associated ditches including approximately 30 Gray Tree Frog, Spring Peeper and American Toad during the May 21 survey. While calling anurans have decreased within the Silver Maple swamp where Plot 16 is located, the vegetated ditches to the west of the plot have become particularly valuable to breeding anurans.

It is difficult to determine the cause of the observed changes at Plot 16. There is not a clear correlation between the observed changes in Plot 16 and the nearby development in Block 9 and 10, or the observed groundwater levels at MW103. The reduction in seasonal standing water within the central portion of the swamp has undoubtedly made the Plot less suitable for anuran breeding; however it would seem that this change is largely related to fluctuations in rainfall from one year to the next. Given the flat topography and localized catchment area for the swamp community, it is unlikely that the grading associated with the SWM pond or commercial development would significantly alter the hydrology for the wetland.

3.6.3 Amphibian Threshold Summary and Contingency Measures

The HCBP Consolidated Monitoring Program (NRSI 2010, p. 41) suggests the following measures when amphibian species decline beyond the established threshold:

- *“Wetland creation where feasible.*
- *Enhancement plantings to improve wetland condition.*
- *Additional monitoring – broaden range of parameters (i.e. water quality).*
- *Increase buffer plantings or alter if necessary.*
- *Provide educational material to neighbouring properties outlining importance of natural features, wildlife and their protection.*
- *Provide additional signage regarding trail closures, etc.”*

While amphibian thresholds were exceeded, none of the above contingency measures are required based on the 2014 findings. Instead, the causes are likely due to natural variation largely influenced by fluctuation in spring temperatures and precipitation from one year to the next. The presence of newly constructed SWM ponds is also likely to have influenced the abundance and distribution of anuran species, in particular American toad and spring peeper which were regularly recorded from within these features. The thresholds that were exceeded are summarized as follows along with recommendations for continued monitoring.

Amphibian Species Diversity

A reduction in species number by more than 2 (between the preconstruction average and 2014 as well as between 2013 and 2014) was not observed during 2014 monitoring. Plots 6 and 16 both showed a decrease of 2 species; however this decrease is within the threshold limit.

Amphibian Species Abundance

A decrease in species abundance beyond the established threshold was recorded at Plots 6, 7 and 16. Within Plot 16 no individuals of Gray Tree Frog or Wood Frog were noted during the 2014 calling anuran surveys. It should be noted that these species were only recorded within this plot in 2012 and data does not suggest that a long-standing population of any of these species is present in Plot 16. Additionally, while Plot 16 contained standing water during the April and May surveys, the wetland did not have standing water during the June survey. The lack of standing water may have discouraged amphibian breeding within Plot 16 as standing water depths dropped throughout the spring.

Monitoring of all anuran plots should continue with a particular focus on changes observed within Plot 16. In the case that anuran diversity and abundance is found to be impacted by development activities, management recommendations may be made in order to mitigate or reverse negative trends.

3.7 Incidental Wildlife Observations

Surveys conducted throughout 2014 resulted in the documentation of a variety of incidental wildlife observations. These observations included birds, herpetofauna, butterflies and mammals that were recorded during the monitoring surveys as well as during construction inspection visits within Phases 1 and Phase 2.

3.7.1 Birds

The birds that were observed incidentally in 2014 are listed in Appendix VIII. The following species were observed on site incidentally during construction inspections, calling anuran surveys, vegetation surveys or during breeding bird point count surveys but beyond the 100m limit of the survey station. Only those species which were not recorded during breeding bird surveys are listed in Table 10.

Table 10. Incidental Bird Species Observed in the Subject Property

Common Name	Scientific Name	COSEWIC[1]	COSSARO[2]	Wellington County[3]
American Woodcock	*Scolopax minor*			
Barred Owl	*Strix varia*			√
Canada Goose	*Branta Canadensis*			
Eastern Phoebe	*Sayonaris phoebe*			
Grasshopper Sparrow	*Ammodramus savannarum*			√
Green Heron	*Butorides virescens*			**
Red-tailed Hawk	*Buteo jamaicensis*	NAR	NAR	
Solitary Sandpiper	*Tringa solitaria*			
Turkey Vulture	*Cathartes aura*			√

[1]COSEWIC 2015; [2]MNRF 2015b; [3]Dougan and Associates 2009

LEGEND
COSEWIC/COSSARO
NAR – Not at Risk
Local Status (Wellington)
√ Significant and rare
** Only habitats that support/recently supported active nests considered significant

3.7.2 Amphibians

A consolidated list of all herpetofaunal species observed by NRSI within the subject property since 1998 is included in Appendix X. In addition to the 5 species documented during calling anuran surveys, American Toad was observed on several occasions during field surveys. In addition to their calls, both Green Frog and Wood Frog were observed during vegetation surveys. Similar to previous monitoring years, numerous calling individuals of both American Toad and Spring Peeper were noted from within the SWM ponds present on site. SWM ponds with regular mention of amphibian activity include those directly east of Downey Road (SWM Pond 2), the SWM swale directly north of Plot 7, and SWM Pond 4 south of Laird Road near Plot 13 (SWM Pond 4). Although these features are relatively new and in the early stages of naturalization, this observed amphibian use indicates that these features may provide suitable breeding habitat for amphibian species. SWM pond locations are shown on Map 1.

3.7.3 Snakes

No snakes were observed within the study area during 2014 surveys. Several species of snake have been observed in previous monitoring years (Appendix X).

3.7.4 Butterflies

A number of butterfly species were observed during the 2014 surveys including Common Wood-Nymph (*Cercyonis pegala*), Little Wood Satyr (*Megisto cymela*), Spring Azure (*Celastrina ladon*), Inornate Ringlet (*Coenonympha tullia inornata*), Clouded Sulphur (*Colias philodice*) and Eastern Tailed Blue (*Cupido comyntas*). Additionally, 1 moth species, Virginia Ctenucha (*Ctenucha virginica*) was observed within the study area.

3.7.5 Mammals

Table 11 lists the mammals that were observed incidentally in 2014, either directly or through their signs (i.e. trails, tracks, scat, dens, etc.). Individuals were observed incidentally during other surveys.

Table 11. Incidental Mammal Species Observed in the Subject Property

Common Name	Scientific Name	Observation Type
Eastern Cottontail	*Sylvilagus floridanus*	Direct observation, scat, tracks
Eastern Chipmunk	*Tamias striatus*	Direct observation, vocalization
White-tailed Deer	*Odocoileus virginianus*	Direct observation, scat, tracks, browse

4.0 Conclusions and Recommendations

The 2014 monitoring year was successful in providing the fifth year of during construction data, contributing to a useful data set that can be compared to pre-construction data and data from future during construction years.

Vegetation

Over the past several years a drying trend has been observed in a number of the vegetation plots within the site. It is noted that reductions in snowmelt and spring precipitation have likely contributed to these trends however annual precipitation following the dry spring of 2012 has rebounded to average levels.

Within Plots 2 and Plot 8, herbaceous cover increased and positively exceeded the pre-construction threshold, a trend observed as a benefit to the site. Plot 1 and Plot 3 both exceeded the lower reach of the threshold in 2014. Within Plot 1, the presence of shallow water has reduced the amount of herbaceous cover in recent years. Given that most species in the plot are adapted to hydric soils and standing water provides a number of benefits to wildlife including anurans, mammals and birds, this change is not seen as a negative impact overall. Herbaceous cover in Plot 3 has been monitored closely due to marked reductions in Ostrich Fern within the plot between pre-construction and the present day. Herbaceous cover in Plot 3 increased by 7.2% between 2013 and 2014. Groundwater levels may be a contributing factor behind fluctuations in vegetation cover within this plot.

Species diversity has generally remained consistent over the monitoring period. A notable decrease in Plot 7 from 47 species in 2013 to just 29 in 2014 may be in part to minor variance in the positioning of the 10x10m plot.

Tree canopy cover within Plot 8 continues to rebound following the installation of restoration plantings to the south of the plot. While these plantings are still too young to contribute canopy cover to the plot, planting inspections note that trees and shrubs in this location are establishing well. The presence of EAB will continue to reduce canopy in areas containing high proportions of Ash trees. It is anticipated that herbaceous species cover in these areas will increase followed by increases in canopy from other existing tree species.

The diversity and abundance of non-native species has remained stable across the site and continued monitoring is recommended to ensure that natural habitats remain diverse and to analyze successional changes in plots adjacent to old agricultural lands.

As per the EIR (NRSI 2009), in order to protect natural features from the effects of sedimentation and erosion, it is recommended that construction monitoring inspections be conducted by an Environmental Monitor or qualified biologist for any development immediately adjacent to natural features, including isolated wetlands within Phase 1A, 1B and 2. This monitoring is intended to ensure that sediment and erosion mitigation measures (i.e. silt fence, vegetated slopes) are effective and natural feature buffers are adhered to. At this time it is not recommended that any additional mitigation measures be implemented on site.

Birds

In 2014 both bird species diversity and bird abundance figures were lower than those documented in 2013 and 2012. Despite the lower diversity and abundance recorded within the plots in 2014, the inclusion of incidental observations brings the species total to 51, which reflects species diversity figures observed prior to 2012. In total, 10 negative threshold exceedances were documented at plots in 2014. Analysis of the data suggests that 2012 and 2013 were exceptional years for bird diversity and in turn bird abundance within the subject property. Fallow fields within Phase 3 continue to provide habitat for a variety of grassland bird species including Bobolink and Eastern Meadowlark. In 2014, no more than 8 individuals of a species were observed at a given plot (many tallies were 6 or fewer on a given survey).

Amphibians

Amphibian monitoring in 2014 continued to show fluctuation in the diversity and abundance of species, both from year to year as well as in comparison with the pre-construction average. Discussion of the observed fluctuations in amphibian data focus largely on climatic conditions including temperature and the extent of vernal pools during the April to June amphibian breeding period. Amphibian breeding may be impacted by dry spring conditions for more than 1 year as populations fluctuate or relocate based upon suitable breeding habitat within the study area.

Monitoring of all anuran plots should continue with a particular focus on changes observed within Plot 16. In the case that anuran diversity and abundance is found to be impacted by development activities, management recommendations may be made in order to mitigate or reverse negative trends.

In 2015, the following construction-related activities are anticipated:

<u>Phase 1, Stage 3</u>

- replacement of specified restoration plantings that were deemed dead, declining or missing by environmental monitor (NRSI) prior to end of the 2 year warrantee period,
- functioning and maintenance of commercial and industrial buildings in Block 5, Block 9 and Block 10,
- continued construction and functioning of buildings in Block 8 and Block 14.

<u>Phase 2</u>

- begin construction of an industrial building within Blocks 8,9 and 26.

It is recommended that during-construction monitoring continue in 2015 as done in 2014, with vegetation, breeding bird, and amphibian call count surveys. NRSI will continue to document all incidental observations of wildlife species within the Business Park.

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MAPS

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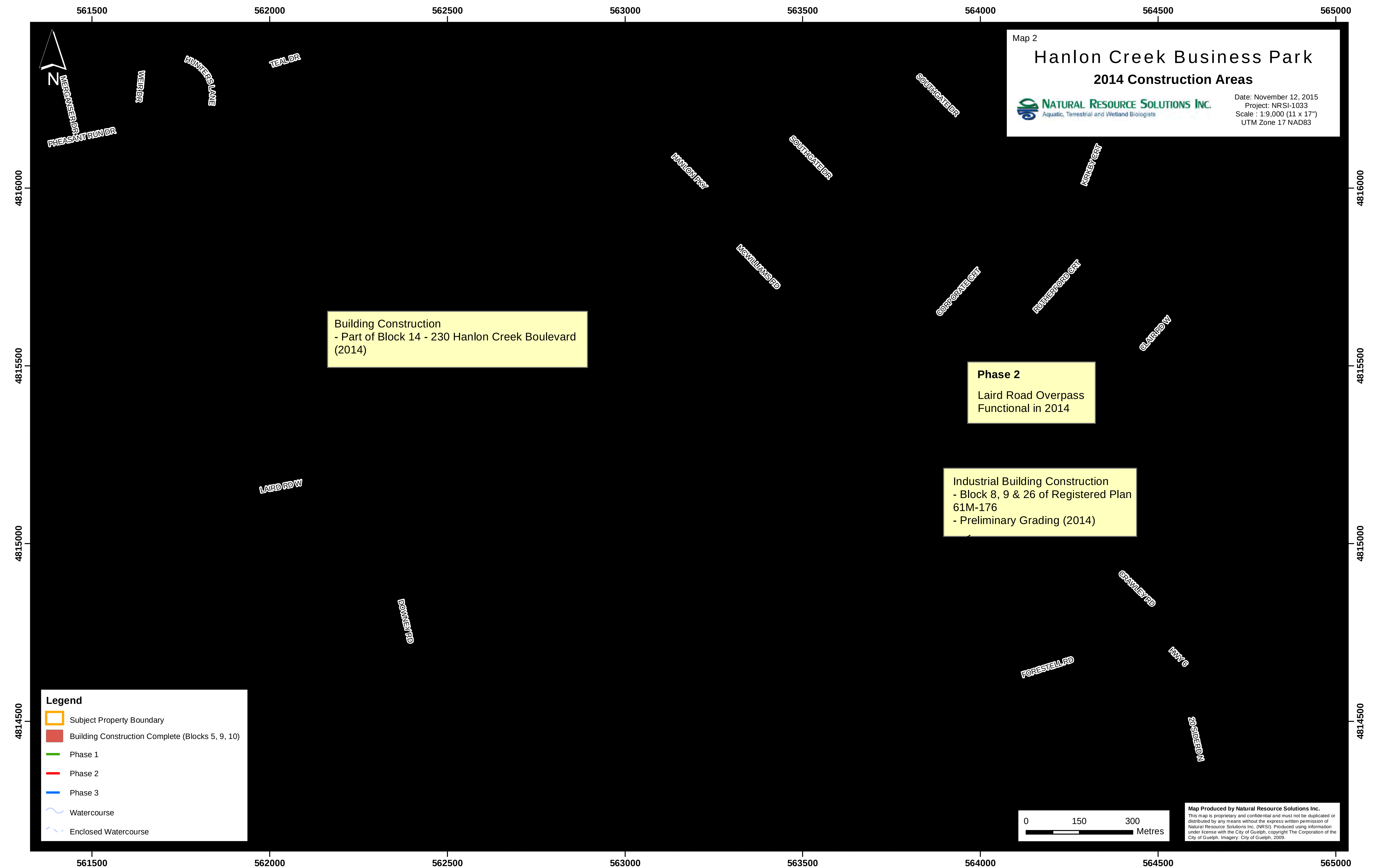

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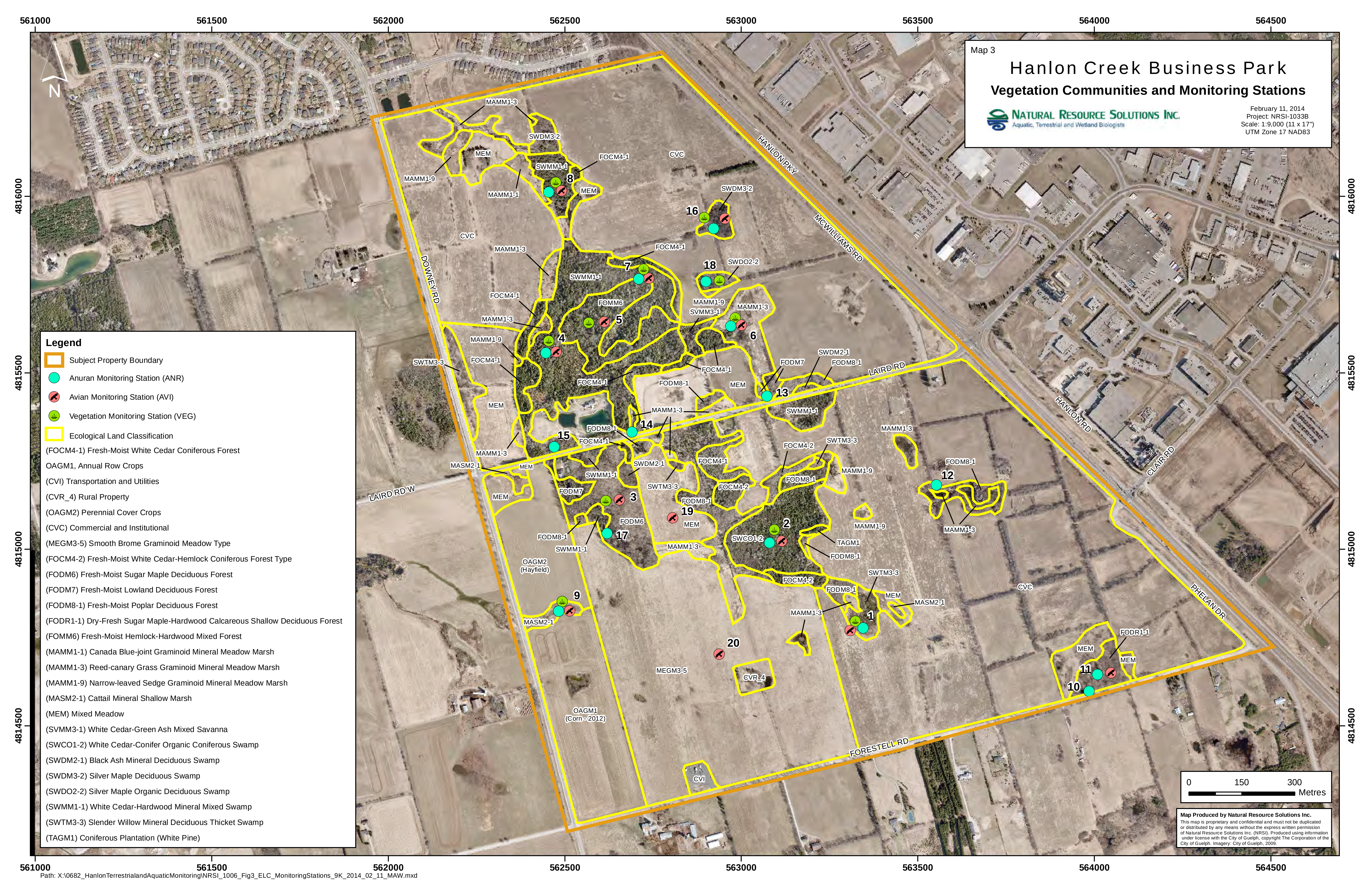
Map 3
Hanlon Creek Business Park
Vegetation Communities and Monitoring Stations
Natural Resource Solutions Inc.
Aquatic, Terrestrial and Wetland Biologists
February 11, 2014
Project: NRSI-1033B
Scale: 1:9,000 (11 x 17")
UTM Zone 17 NAD83
Legend
Subject Property Boundary
Anuran Monitoring Station (ANR)
Avian Monitoring Station (AVI)
Vegetation Monitoring Station (VEG)
Ecological Land Classification
(FOCM4-1) Fresh-Moist White Cedar Coniferous Forest
OAGM1, Annual Row Crops
(CVI) Transportation and Utilities
(CVR_4) Rural Property
(OAGM2) Perennial Cover Crops
(CVC) Commercial and Institutional
(MEGM3-5) Smooth Brome Graminoid Meadow Type
(FOCM4-2) Fresh-Moist White Cedar-Hemlock Coniferous Forest Type
(FODM6) Fresh-Moist Sugar Maple Deciduous Forest
(FODM7) Fresh-Moist Lowland Deciduous Forest
(FODM8-1) Fresh-Moist Poplar Deciduous Forest
(FODR1-1) Dry-Fresh Sugar Maple-Hardwood Calcareous Shallow Deciduous Forest
(FOMM6) Fresh-Moist Hemlock-Hardwood Mixed Forest
(MAMM1-1) Canada Blue-joint Graminoid Mineral Meadow Marsh
(MAMM1-3) Reed-canary Grass Graminoid Mineral Meadow Marsh
(MAMM1-9) Narrow-leaved Sedge Graminoid Mineral Meadow Marsh
(MASM2-1) Cattail Mineral Shallow Marsh
(MEM) Mixed Meadow
(SVMM3-1) White Cedar-Green Ash Mixed Savanna
(SWCO1-2) White Cedar-Conifer Organic Coniferous Swamp
(SWDM2-1) Black Ash Mineral Deciduous Swamp
(SWDM3-2) Silver Maple Deciduous Swamp
(SWDO2-2) Silver Maple Organic Deciduous Swamp
(SWMM1-1) White Cedar-Hardwood Mineral Mixed Swamp
(SWTM3-3) Slender Willow Mineral Deciduous Thicket Swamp
(TAGM1) Coniferous Plantation (White Pine)
0 150 300 Metres
Map Produced by Natural Resource Solutions Inc.
This map is proprietary and confidential and must not be duplicated or distributed by any means without the express written permission of Natural Resource Solutions Inc. (NRSI). Produced using information under license with the City of Guelph, copyright The Corporation of the City of Guelph. Imagery: City of Guelph, 2009.
HANLON PKY
MCWILLIAMS RD
DOWNEY RD
LAIRD RD
LAIRD RD W
HANLON RD
CLAIR RD
PHELAN DR
FORESTELL RD
OAGM2 (Hayfield)
OAGM1 (Corn - 2012)
MEGM3-5
Path: X:\0682_HanlonTerrestrialandAquaticMonitoring\NRSI_1006_Fig3_ELC_MonitoringStations_9K_2014_02_11_MAW.mxd

APPENDIX I
Vegetation Species Observed in the Subject Property 2006 - 2014

Appendix I. Vegetation Species Observed in the Study Area (2006 - 2014)

									Wellington	NRSI								
SCIENTIFIC NAME	COMMON NAME	CC	CW	Weed	+	SRANK[1]	COSEWIC[2]	COSSARO[3]	County[4]	2006	2007	2008	2009	2010	2011	2012	2013	2014
Abies balsamea	Balsam Fir	5	-3			S5				√	√	√	√	√	√	√	√	√
Acer rubrum	Red Maple	4	0			S5				√	√	√	√	√	√	√	√	√
Acer saccharinum	Silver Maple	5	-3			S5				√	√	√	√	√	√	√	√	√
Acer saccharum ssp. saccharum	Sugar Maple	4	3			S5				√	√	√	√	√	√	√	√	√
Actaea spp.	Baneberry species										√		√					√
Agrostis stolonifera	Redtop		-3			S5												√
Alisma spp.	Water Plantain species											√						
Alliaria petiolata	Garlic Mustard	*	0	-3	+	SE5									√			
Allium tricoccum	Wild Leek	7	2			S5					√							
Amelanchier arborea	Downy Serviceberry	5	3			S5											√	
Arabis glabra	Tower-mustard	0	0			S5						√						
Aralia nudicaulis	Wild Sarsaparilla	4	3			S5				√	√	√	√	√	√	√	√	√
Arctium minus	Common Burdock	*	5	-2	+	SE5					√						√	
Arctium species	Burdock species															√		
Arisaema triphyllum	Jack-in-the-pulpit	5	-2			S5				√	√	√	√	√	√	√	√	√
Aronia melanocarpa	Black Chokeberry	7	-3			S5										√		
Asclepias incarnata ssp. Incarnata	Swamp Milkweed	6	-5			S5				√	√						√	√
Asclepias syriaca	Common Milkweed	0	5			S5				√								√
Aster species	Aster species												√		√		√	
Athyrium filix-femina var. angustum	Northeastern Lady Fern	4	0			S5							√	√				
Betula alleghaniensis	Yellow Birch	6	0			S5				√	√	√	√	√	√	√	√	√
Bidens cernua	Nodding Beggarticks	2	-5			S5								√				√
Bidens frondosa	Devil's beggarticks	3	-3			S5										√	√	√
Bidens tripartita	Beggarticks	4	-3			S5					√	√						
Boehmeria cylindrica	False Nettle	4	-5			S5										√		√
Bromus inermis ssp. inermis	Smooth Brome	*	5	-3	+	SE5					√				√			√
Calamagrostis canadensis	Canada Blue-joint	4	-5			S5				√	√	√	√	√	√	√	√	√
Caltha palustris	Marsh Marigold	5	-5			S5				√	√	√	√	√	√	√	√	√
Cardamine pensylvanica	Pennsylvania Bitter Cress	6	-3			S5							√					
Carex albursina	White bear Sedge	7	5			S5										√		
Carex aquatilis	Water Sedge	7	-5			S5							√	√	√	√	√	√
Carex arctata	Compressed Sedge	5	5			S5							√					
Carex bebbii	Bebb's Sedge	3	-5			S5											√	
Carex blanda	Smooth Sedge	3	0			S5										√	√	√
Carex flava	Yellow Sedge	5	-5			S5										√	√	
Carex gracillima	Graceful Sedge	4	3			S5							√	√		√	√	√
Carex hystercina	Porcupine Sedge	5	-5			S5										√		
Carex intumescens	Bladder Sedge	6	-4			S5							√		√	√		
Carex lacustris	Lake Sedge	5	-5			S5				√		√	√	√	√	√	√	√
Carex laxiflora	Loose-flowered Sedge	5	0			S5							√				√	√
Carex lupulina	Hop Sedge	6	-5			S5										√	√	√
Carex pensylvanica	Pennsylvania Sedge	5	5			S5										√		
Carex species	Sedge species									√	√	√	√	√	√		√	
Carex stipata	Awl-fruited Sedge	3	-5			S5				√	√	√	√	√	√	√		√
Carex stricta	Stiff Sedge	4	-5			S5						√	√	√			√	
Carex utriculata	Beaked Sedge	7	-5			S5					√		√		√			
Carex vulpinoidea	Fox Sedge	3	-5			S5						√	√	√	√	√	√	√
Carpinus caroliniana	Blue Beech	6	0			S5										√		
Cerastium fontanum	Mouse-eared Chickweed	*	3	-1	+	SE5											√	
Chelone glabra	Turtlehead	7	-5			S5										√	√	√
Cicuta bulbifera	Bulbous Water-hemlock	5	-5			S5						√	√	√	√	√		√
Cicuta maculata	Spotted Water Hemlock	6	-5			S5				√	√	√	√	√	√	√	√	√

SCIENTIFIC NAME	COMMON NAME	CC	CW	Weed	+	SRANK[1]	COSEWIC[2]	COSSARO[3]	Wellington County[4]	NRSI								
										2006	2007	2008	2009	2010	2011	2012	2013	2014
Circaea alpina	Dwarf Enchanter's Nightshade	6	-3			S5				√			√			√	√	√
Circaea lutetiana ssp. canadensis	Yellowish Enchanter's Nightshade																√	√
Circaea quadrisulcata	Enchanter's Nightshade	3	3			S5				√	√	√	√	√	√	√		
Cirsium arvense	Canada Thistle	*	3	-1	+	SE5				√	√	√	√	√	√	√	√	√
Cirsium muticum	Swamp Thistle	8	-5			S5											√	√
Cirsium species	Thistle species															√		
Cirsium vulgare	Bull Thistle	4	5			S5											√	
Clintonia borealis	Bluebead Lily	7	-1			S5					√	√	√	√	√	√	√	√
Coptis trifolia	Goldthread	7	-3			S5					√							
Cornus alternifolia	Alternate-leaved Dogwood	6	5			S5				√	√	√	√	√	√	√	√	√
Cornus amomum	Silky Dogwood	5	-4			S5										√	√	√
Cornus foemina	Gray Dogwood	2	-2			S5											√	
Cornus stolonifera	Red-Osier Dogwood	2	-3			S5				√	√	√	√	√	√	√	√	√
Corylus americana	American Hazel	5	4			S5								√				
Crataegus species	Hawthorn species									√	√				√			
Cypripedium calceolus var. parviflorum	Small Yellow Lady's Slipper	7	-1			S5							√					
Cysptopteris tenuis	Mackay's Fragile Fern	6	5									√						√
Cystopteris bulbifera	Bulblet Fern	5	-2			S5				√	√		√	√	√	√	√	√
Dactylis glomerata	Orchard Grass	*	3	-1	+	SE5										√	√	√
Daucus carota	Queen Anne's Lace	*	5	-2	+	SE5					√		√	√	√	√	√	√
Doellingeria umbellata	Flat-top White Aster	6	-3			S5										√		
Dryopteris carthusiana	Spinulose Wood Fern	5	-2			S5				√	√	√	√	√	√	√	√	√
Dryopteris clintoniana	Clinton's Wood Fern	7	-4			S4			R		√			√	√			
Dryopteris cristata	Crested Wood Fern	7	-5			S5				√	√	√	√	√	√		√	√
Dryopteris marginalis	Marginal Wood Fern	5	3			S5							√	√	√	√	√	√
Dryopteris sp.	Wood Fern Species																	√
Echinochloa crusgalli	Barnyard Grass	*	3	-1	+	SE5							√	√				√
Echinocystis lobata	Wild Cucumber	3	-2			S5					√	√	√		√	√	√	√
Eleocharis smallii	Small's Spike-rush	6	-5			S5								√				
Elymus repens	Quack Grass	*	3	-3	+	SE5						√					√	
Epilobium ciliatum ssp. glandulosum	Willow-herb	6	3			SU										√		√
Epilobium hirsutum	Hairy Willow-Herb	*	-4	-2	+	SE5							√	√	√	√	√	
Epilobium var	Willow-Herb species																√	
Epipactis helleborine	Helleborine	*	5	-2	+	SE5						√	√	√		√		√
Equisetum arvense	Field Horsetail	0	0			S5					√	√	√	√	√	√	√	√
Equisetum palustre	Marsh Horsetail	10	-3			S5			R	√	√				√			
Equisetum pratense	Meadow Horsetail	8	-3			S5			R	√		√	√	√	√	√		√
Equisetum scirpoides	Dwarf Scouring-rush	7	-1			S5								√			√	√
Erigeron annuus	Daisy Fleabane																	√
Erigeron species	Fleabane species										√					√		
Eupatorium maculatum	Spotted Joe-Pye Weed	3	-5							√	√	√	√	√	√	√	√	√
Eupatorium perfoliatum	Boneset	2	-4			S5					√	√				√	√	√
Eurybia macrophylla	Large-leaved Aster	5	5			S5				√			√					
Euthamia graminifolia	Grass-leaved Goldenrod	2	-2			S5						√	√	√	√	√	√	√
Fagus grandifolia	American Beech	6	3			S5					√							
Festuca arundinacea	Tall Fescue	*	2	-1	+	SE5											√	√
Fragaria vesca	Woodland Strawberry	4	4							√	√	√	√		√	√	√	√
Fragaria virginiana	Wild Strawberry	2	1			S5					√	√	√	√	√	√	√	√
Fraxinus americana	White Ash	4	3			S5				√	√	√	√	√	√	√	√	√
Fraxinus nigra	Black Ash	7	-4			S5				√	√	√	√	√	√	√	√	√
Fraxinus pennsylvanica var. subintegerrina	Green Ash	3	-3												√	√	√	√
Galium asprellum	Rough Bedstraw	6	-5			S5				√		√	√					
Galium palustre	Marsh Bedstraw	5	-5			S5				√	√	√	√	√	√	√	√	√
Galium triflorum	Sweet-scented Bedstraw	4	2			S5				√		√	√	√				
Geranium robertianum	Herb Robert	*	5	-2	+	SE5				√	√	√	√	√	√		√	√

SCIENTIFIC NAME	COMMON NAME	CC	CW	Weed	+	SRANK[1]	COSEWIC[2]	COSSARO[3]	Wellington County[4]	NRSI								
										2006	2007	2008	2009	2010	2011	2012	2013	2014
Geum aleppicum	Yellow Avens	2	-1			S5						√	√	√	√	√	√	√
Geum canadense	White Avens	3	0			S5					√						√	√
Geum laciniatum	Rough Avens	4	-3			S4			R		√				√	√		
Geum species	Avens species									√							√	√
Glyceria species	Manna Grass species														√			
Glyceria striata	Fowl Manna Grass	3	-5			S5					√		√		√	√	√	√
Gymnocarpium dryopteris	Oak Fern	7	0			S5					√	√	√	√		√	√	
Hamamelis virginiana	Witch Hazel	6	3			S5			R						√			
Heracleum lanatum	Cow Parsnip	3	-3			S5										√		
Hieracium species	Hawkweed species											√						
Hydrocotyle americana	Marsh-Water Pennywort	7	-5			S5				√			√					
Hydrophyllum virginianum	Virginia Waterleaf	6	-2			S5						√		√				
Ilex verticillata	Winterberry	5	-4			S5									√	√	√	√
Impatiens capensis	Spotted Jewelweed	4	-3			S5				√	√		√	√	√	√	√	√
Impatiens pallida	Pale Jewelweed	7	-3			S5			R		√	√			√			
Iris species	Iris species	0	0								√							
Juncus effusus	Soft Rush	4	-5										√	√			√	
Juncus species	Rush species									√	√							
Juncus tenuis	Path Rush	0	0			S5				√		√	√	√	√	√	√	√
Lactuca serriola	Prickly Lettuce	*	0			SE5				√			√					
Leersia oryzoides	Rice Cutgrass	3	-5			S5				√			√		√	√	√	√
Linaria vulgaris	Butter-and-eggs	*	5	-1	+	SE5						√						
Liparis loeselii	Fen Twayblade	5	-4			S4S5											√	
Lobelia siphilitica	Great Lobelia	6	-4			S5								√		√		
Lonicera canadensis	Fly Honeysuckle	6	3			S5										√		
Lonicera tatarica	Tartarian Honeysuckle	*	3	-3	+	SE5				√	√	√	√	√	√	√	√	√
Lotus corniculatus	Bird's-foot Trefoil	*	1	-2	+	SE5				√	√	√	√	√	√	√	√	√
Lycopus americanus	American Water-horehound	4	-5			S5											√	√
Lycopus uniflorus	Northern Bugleweed	5	-5			S5				√	√	√	√	√	√	√	√	√
Lysimachia ciliata	Fringed Loosestrife	4	-3			S5					√	√	√	√	√	√	√	√
Lysimachia nummularia	Moneywort	*	-4	-3	+	SE5					√							
Lysimachia terrestris	Swamp Candles	6	-5			S5					√		√		√	√	√	
Lysimachia thyrsiflora	Tufted Loosestrife	7	-5								√	√	√	√	√	√		√
Lythraceae spp.	Loosestrife species											√						
Lythrum salicaria	Purple loosestrife	*	-5	-3	+	SE5										√		
Maianthemum canadense	Canada Mayflower	5	0			S5				√	√	√	√	√	√	√	√	√
Maianthemum racemosum	False Solomon's Seal	4	3							√	√	√			√	√		√
Maianthemum stellatum	Star Flowered False Solomon's-seal	6	1			S5						√	√	√				
Malva neglecta	Common Mallow	*	5	-1	+	SE5									√			
Marchantia polymorpha	Common Liverwort					S5										√		
Matteuccia struthiopteris	American Ostrich Fern	5	-3							√	√	√	√	√	√	√	√	√
Medicago lupulina	Black Medick	*	1	-1	+	SE5								√	√	√	√	
Mentha arvensis	Common Mint	3	-3							√	√		√	√	√	√	√	√
Mentha X piperita	Pepper Mint	*	-5	-1		SE4										√		
Mitella nuda	Naked Miterwort	6	-3			S5										√	√	√
Myosotis sp.	Forget-me-not species																	√
Nasturtium officinale	Watercress	*	-5	-1	+	SE?							√	√	√	√	√	√
Onoclea sensibilis	Sensitive Fern	4	-3			S5				√	√	√	√	√	√	√	√	√
Osmunda cinnamomea	Cinnamon Fern	7	-3			S5					√		√	√	√	√	√	√
Ostrya virginiana	Ironwood	4	4			S5				√		√						
Oxalis stricta	Upright Yellow Wood Sorrel	0	3			S5										√		
Parthenocissus vitacea	Woodbine	3	3			S5											√	√
Parthenocissus quinquefolia	Virginia Creeper	6	1			S4?				√	√	√	√	√	√	√		
Phalaris arundinacea	Reed Canary Grass	0	-4			S5					√	√	√	√	√	√	√	√

SCIENTIFIC NAME	COMMON NAME	CC	CW	Weed	+	SRANK[1]	COSEWIC[2]	COSSARO[3]	Wellington County[4]	NRSI								
										2006	2007	2008	2009	2010	2011	2012	2013	2014
Phleum pratense	Timothy	*	3	-1	+	SE5						√		√	√	√	√	√
Picea glauca	White Spruce	6	3			S5				√	√	√	√	√	√			
Pilea pumila	Clearweed	5	-3			S5			R			√					√	
Pinus strobus	Eastern White Pine	4	3			S5				√	√	√	√	√	√	√	√	
Plantago lanceolata	English Plantain	*	0	-1	+	SE5								√				
Plantago major	Common Plantain	*	-1	-1	+	SE5								√	√			
Poa nemoralis	Woodland Spear Grass	0	0	-1		SE3							√					
Poa palustris	Fowl Meadow Grass	5	-4			S5									√	√	√	√
Poa pratensis	Kentucky Blue Grass	0	1								√	√	√	√	√	√	√	√
Poa species	Grass species									√	√	√	√	√	√	√	√	√
Polygonatum pubescens	Hairy Solomon's Seal	5	5			S5					√	√			√	√	√	
Polygonum amphibium	Water Smartweed	5	-5												√			
Polygonum species	Smartweed species																√	
Polygonum virginianum	Jumpseed	6	0			S4										√		
Polystichum acrostichoides	Christmas Fern	5	5			S5				√		√	√	√	√			
Populus tremuloides	Trembling Aspen	2	0			S5										√		√
Potentilla recta	Sulphur Cinquefoil	*	5	-2	+	SE5										√	√	
Prenanthes alba	White Rattlesnake-root	6	3			S5				√								
Prunella vulgaris ssp. lanceolata	Selfheal	5	5			S5								√	√	√	√	√
Prunus pensylvanica	Pin Cherry	3	4			S5								√				
Prunus serotina	Black Cherry	3	3			S5				√	√	√	√	√	√	√	√	√
Prunus virginiana	Chokecherry	2	1									√	√		√		√	√
Quercus macrocarpa	Bur Oak	5	1			S5												√
Quercus rubra	Red Oak	6	3			S5								√				
Quercus species	Oak species																√	√
Ranunculus abortivus	Small-flowered Buttercup	2	-2			S5				√	√						√	
Ranunculus acris	Tall Buttercup	*	-2	-2	+	SE5				√	√		√	√	√	√	√	√
Ranunculus flabellaris	Yellow Water-crowfoot	7	-5			S4?			R			√			√			
Ranunculus hispidus var caricetorum	Swamp Buttercup	5	-5							√			√			√	√	√
Ranunculus pensylvanicus	Bristly Buttercup	3	-5			S5						√						
Ranunculus recurvatus	Hooked Buttercup	4	-3								√	√				√		
Ranunculus repens	Creeping Buttercup	0	-1	-1		SE5					√			√		√	√	
Ranunculus sceleratus	Cursed Crowfoot	2	-5								√		√	√				
Ranunculus species	Buttercup species														√			
Rhamnus cathartica	Common Buckthorn	*	3	-3	+	SE5				√	√	√	√	√	√	√	√	√
Rhamnus frangula	Glossy Buckthorn	*	-1	-3	+					√	√	√	√	√	√	√	√	√
Rhynchospora alba	White Beaked-rush	10	-5			S5										√		
Ribes americanum	Wild Black Currant	4	-3			S5				√	√	√		√	√	√		√
Ribes hirtellum	Smooth Gooseberry	6	-3			S5			R				√					
Ribes lacustre	Bristly Black Currant	7	-3			S5					√							
Ribes rubrum	Red Currant	*	5	-2	+	SE5						√			√			
Ribes species	Currant species									√	√			√	√			
Ribes triste	Swamp Red Currant	6	-5			S5									√	√		
Rubus allegheniensis	Common Blackberry	2	2			S5					√				√			
Rubus idaeus	Red Raspberry	0	-2							√	√	√	√	√	√		√	√
Rubus occidentalis	Black Raspberry	2	5			S5							√			√		
Rubus parviflorus	Sparse-flowered Thimbleberry	7	2			S4									√			
Rubus pubescens	Dwarf Raspberry	4	-4			S5				√	√	√	√	√	√	√	√	√
Rumex crispus	Curled Dock	*	-1	-2	+	SE5						√		√	√			
Sagittaria latifolia	Common Arrowhead	4	-5			S5										√	√	√
Salix bebbiana	Bebb's Willow	4	-4			S5						√			√			
Salix eriocephala	Heart-leaved Willow	4	-3			S5								√	√	√	√	√
Salix exigua	Sandbar Willow	3	-5			S5				√								
Salix lucida	Shining Willow	5	-4			S5									√			

SCIENTIFIC NAME	COMMON NAME	CC	CW	Weed	+	SRANK[1]	COSEWIC[2]	COSSARO[3]	Wellington County[4]	NRSI 2006	2007	2008	2009	2010	2011	2012	2013	2014
Salix petiolaris	Slender Willow	3	-4			S5				√		√	√	√	√	√	√	√
Salix species	Willow species										√			√	√			
Sambucus canadensis	Common Elderberry	5	-2			S5				√				√	√		√	√
Sanguinaria canadensis	Bloodroot	5	4			S5									√			
Scirpus americanus	Common Three Square	6	-5							√								
Scirpus atrovirens	Dark Green Bulrush	3	-5			S5						√	√	√	√	√	√	√
Scirpus cyperinus var. cyperinus	Wool-grass	4	-5			S5												√
Scutellaria galericulata	Common Skullcap	6	-5			S5				√		√	√		√	√	√	√
Scutellaria lateriflora	Mad-dog Skullcap	5	-5			S5				√	√			√		√		
Scutellaria species	Skullcap species									√								
Silene cucubalus	Bladder Campion	*	5	-1	+					√								
Sium suave	Water Parsnip	4	-5			S5				√	√	√		√	√		√	√
Solanum dulcamara	Bittersweet Nightshade	*	0	-2	+	SE5				√	√	√	√	√	√	√	√	√
Solidago altissima	Tall Goldenrod	1	3							√				√	√	√	√	√
Solidago caesia	Blue-stem Goldenrod	5	3			S5										√		
Solidago canadensis	Canada Goldenrod	1	3			S5				√	√	√	√	√	√	√	√	√
Solidago flexicaulis	Zig-zag Goldenrod	6	3			S5				√				√	√	√	√	√
Solidago gigantea	Late Goldenrod	4	-3			S5									√		√	√
Solidago nemoralis	Gray Goldenrod	2	5									√						
Solidago patula	Rough-leaved Goldenrod	8	-5			S5			R		√	√			√	√		√
Solidago rugosa	Rough-stemmed Goldenrod	4	-1			S5										√	√	√
Solidago species	Goldenrod species									√	√	√	√	√				
Solidago uliginosa	Bog Goldenrod	9	-5			S5											√	
Sonchus arvensis	Field Sow Thistle	*	1	-1	+							√		√			√	
Sorbus americana	Mountain Ash	8	-1			S5			R					√				
Spirodela polyrhiza	Duckweed	4	-5			S5					√		√	√				
Stachys species	Hedge Nettle species															√		
Symphyotrichum lanceolatum	Panicled Aster	3	-3											√	√	√	√	√
Symphyotrichum lateriflorum	Calico Aster	3	-2												√	√	√	√
Symphyotrichum novae-angliae	New England Aster	2	-3			S5					√	√		√	√	√	√	√
Symphyotrichum puniceum	Purple Stemmed Aster	6	-5			S5				√	√		√	√	√	√	√	√
Taraxacum officinale	Common Dandelion	*	3	-2	+	SE5				√	√	√	√	√	√	√	√	√
Thelypteris palustris	Marsh Fern	5	-4							√	√	√	√		√	√	√	√
Thuja occidentalis	Eastern White Cedar	4	-3			S5				√	√	√	√	√	√	√	√	√
Tiarella cordifolia	Foam Flower	6	1			S5					√			√	√			
Toxicodendron radicans ssp. negundo	Poison Ivy	5	-1							√	√		√		√	√		√
Toxicodendron rydbergii	Western Poison-ivy	0	0			S5											√	
Trientalis borealis	Starflower	6	-1							√	√		√		√	√	√	
Trifolium hybridum	Alsike Clover	*	1	-1	+					√				√	√		√	
Trifolium pratense	Red Clover	*	2	-2	+	SE5						√						
Trifolium repens	White Clover	*	2	-1	+	SE5								√				
Trillium species	Trillium species																√	√
Tsuga canadensis	Eastern Hemlock	7	3			S5				√	√	√	√	√	√	√	√	√
Tussilago farfara	Coltsfoot	*	3	-2	+	SE5				√	√	√	√	√	√	√	√	√
Typha angustifolia	Narrow-leaved Cattail	3	-5			S5								√	√		√	√
Typha latifolia	Common Cattail	3	-5			S5				√	√	√	√	√			√	
Ulmus americana	White Elm	3	-2			S5				√	√	√	√	√	√	√	√	√
Urtica dioica ssp. gracilis	American Stinging Nettle	2	-1			S5											√	
Verbascum thapsus	Common Mullein	*	5	-2	+	SE5											√	
Veronica americana	American Brooklime	6	-5			S5										√		
Veronica anagallis-aquatica	Water Speedwell	*	-5	-1	+	SE5				√					√	√		
Veronica officinalis	Common Speedwell	*	5	-2	+	SE5						√	√		√	√	√	
Veronica persica	Bird's-eye Speedwell	*	5	-1	+	SE4										√		

SCIENTIFIC NAME	COMMON NAME	CC	CW	Weed	+	SRANK[1]	COSEWIC[2]	COSSARO[3]	Wellington County[4]	NRSI 2006	2007	2008	2009	2010	2011	2012	2013	2014
Veronica scutellata	Marsh Speedwell	7	-5			S5				√		√						
Veronica species	Speedwell species										√	√	√	√				
Viburnum trilobum	High-bush Cranberry	5	-3			S5				√			√	√	√		√	√
Viburnum opulus	Guelder-rose	*	0	-1	+	SE4										√	√	
Viola species	Violet Species														√			
Vitis riparia	Riverbank Grape	0	-2			S5				√	√	√	√	√	√	√	√	√
Waldsteinia fragarioides	Barren Strawberry	5	5			S5					√			√	√			
Total					**43**				**11**	**96**	**109**	**108**	**117**	**123**	**138**	**147**	**146**	**136**

[1]MNRF 2015a; [2]COSEWIC 2015; [3]MNRF 2015b, [4]Dougan & Associates 2009

LEGEND	
Floristic Information	
CC	Coefficient of Conservatism
CW	Coefficient of Wetness
Weed	Weediness Index
+	non-native species
SRANK	
S3	Vulnerable
S4	Apparently Secure
S5	Secure
?	Uncertainty about rank
SE	Exotic species
Wellington Status	
R	Rare

APPENDIX II

Herbaceous Species Observed by Plot 2014

Appendix II. Vegetation Species Observed by Plot (2014)

* Frequency is the percent chance the species is found in the five subplots. E.g. If the species was found in only one subplot, its frequency is 20%. If it was found in 4 subplots, its frequency is 80%.

Sub plot #	Scientific Name	Common Name	CC	CW	Weed	Number/m^2	Cover (%)/m^2	Frequency (%)*
Vegetation Plot 001		**MAMM1-3**	**Reed-canary Grass Graminoid Mineral Meadow Marsh**					
1	Impatiens capensis	Spotted Jewelweed	4	-3	0	18	4	100
	Galium palustre	Marsh Bedstraw	5	-5	0	1	1	80
	Calamagrostis canadensis	Canada Blue-joint	4	-5	0		5	20
	Equisetum arvense	Field Horsetail	0	0	0	5	7	80
	Poa palustris	Fowl Meadow Grass	5	-4	0		10	20
	Carex aquatilis	Water Sedge	7	-5	0		15	100
	Asclepias incarnata	Swamp Milkweed	6	-5	0	1	1	60
	Epilobium species	Willow-Herb species				1	1	20
2	Impatiens capensis	Spotted Jewelweed	4	-3	0	50	20	100
	Equisetum arvense	Field Horsetail	0	0	0	7	15	80
	Asclepias incarnata	Swamp Milkweed	6	-5	0	2	2	60
	Carex aquatilis	Water Sedge	7	-5	0		4	100
	Epilobium hirsutum	Hairy Willow-Herb	*	-4	-2	1	0.5	20
	Sium suave	Water Parsnip	4	-5	0	1	0.5	60
	Galium palustre	Marsh Bedstraw	5	-5	0	2	1	80
3	Solidago canadensis	Canada Goldenrod	1	3	0	4	5	20
	Impatiens capensis	Spotted Jewelweed	4	-3	0	50	30	100
	Sium suave	Water Parsnip	4	-5	0	4	2	60
	Carex aquatilis	Water Sedge	7	-5	0		10	100
	Equisetum arvense	Field Horsetail	0	0	0	4	8	80
	Galium palustre	Marsh Bedstraw	5	-5	0	3	2	80
	Symphyotrichum puniceum	Purple Stemmed Aster	6	-5	0	2	1	20
	Lycopus americanus	American Water-horehound	4	-5	0	1	1	40
	Carex lacustris	Lake Sedge	5	-5	0		5	40
	Carex vulpinoidea	Fox Sedge	3	-5	0		2	20
4	Carex lacustris	Lake Sedge	5	-5	0		2	40
	Lysimachia terrestris	Swamp Candles	6	-5	0	1	1	20
	Impatiens capensis	Spotted Jewelweed	4	-3	0	30	15	100
	Dryopteris cristata	Crested Wood Fern	7	-5	0	2	4	20
	Symphyotrichum lanceolatum	Panicled Aster	3	-3	0	2	2	20
	Carex aquatilis	Water Sedge	7	-5	0		1	100
	Galium palustre	Marsh Bedstraw	5	-5	0	2	1	80
5	Phalaris arundinacea	Reed Canary Grass	0	-4	0		5	20
	Carex aquatilis	Water Sedge	7	-5	0		85	100
	Impatiens capensis	Spotted Jewelweed	4	-3	0	20	8	100
	Sium suave	Water Parsnip	4	-5	0	5	2	60
	Equisetum arvense	Field Horsetail	0	0	0	2	2	80
	Asclepias incarnata	Swamp Milkweed	6	-5	0	1	0.5	60
	Lycopus americanus	American Water-horehound	4	-5	0	1	0.5	40

Sub plot #	Scientific Name	Common Name	CC	CW	Weed	Number/m^2	Cover (%)/m^2	Frequency (%)
Vegetation Plot 002		**SWCO1-2**	**White Cedar - Conifer Organic Coniferous Swamp**					
1	Caltha palustris	Marsh Marigold	5	-5	0	5	20	40
	Circaea lutetiana ssp. canadensis	Yellowish Enchanter's Nights	3	3	0	2	1	20
	Solidago canadensis	Canada Goldenrod	1	3	0	4	1	20
	Equisetum arvense	Field Horsetail	0	0	0	2	4	20
	Epilobium hirsutum	Hairy Willow-Herb	*	-4	-2	1	1	20
	Cirsium var	Thistle species				4	2	40
	Symphyotrichum novae-angliae	New England Aster	2	-3	0	1	1	20
2	Impatiens capensis	Spotted Jewelweed	4	-3	0	15	80	80
	Cirsium var	Thistle species				3	5	40
	Dryopteris carthusiana	Spinulose Wood Fern	5	-2	0	1	1	20
3	Impatiens capensis	Spotted Jewelweed	4	-3	0	15	40	80
	Eupatorium perfoliatum	Boneset	2	-4	0	4	7	40
	Cirsium muticum	Swamp Thistle	8	-5	0	1	2	20
	Pilea pumila	Clearweed	5	-3	0	1	1	20
4	Impatiens capensis	Spotted Jewelweed	4	-3	0	20	70	80
5	Eupatorium perfoliatum	Boneset	2	-4	0	1	2	40
	Impatiens capensis	Spotted Jewelweed	4	-3	0	40	80	80
	Caltha palustris	Marsh Marigold	5	-5	0	1	3	40
	Lycopus americanus	American Water-horehound	4	-5	0	1	2	20
	Cirsium arvense	Canada Thstle	*	3	-1	1	1	20
	Solidago spp.	Goldenrod species	0	0	0	1	1	20

Sub plot #	Scientific Name	Common Name	CC	CW	Weed	Number/m^2	Cover (%)/m^2	Frequency (%)
Vegetation Plot 003		**FODM6**	**Fresh-Moist Sugar Maple Deciduous Forest**					
1	Matteuccia struthiopteris	Ostrich Fern	5	-3	0	8	8	100
	Circaea lutetiana ssp. canadensis	Yellowish Enchanter's Nights	3	3	0	1	0.5	20
	Trillium var	Trillium species				9	3	40
2	Matteuccia struthiopteris	Ostrich Fern	5	-3	0	3	5	100
3	Matteuccia struthiopteris	Ostrich Fern	5	-3	0	1	3	100
4	Matteuccia struthiopteris	Ostrich Fern	5	-3	0	3	5	100
5	Matteuccia struthiopteris	Ostrich Fern	5	-3	0	5	20	100
	Trillium var	Trillium species				2	1	40

Sub plot #	Scientific Name	Common Name	CC	CW	Weed	Number/m^2	Cover (%)/m^2	Frequency (%)
Vegetation Plot 004		**SWMM1-1**	**White Cedar - Hardwood Mineral Mixed Swamp**					
1	Onoclea sensibilis	Sensitive Fern	4	-3	0	1	0.5	60
2	Onoclea sensibilis	Sensitive Fern	4	-3	0	17	7	60
	Dryopteris carthusiana	Spinulose Wood Fern	5	-2	0	1	0.5	40
	Dryopteris marginalis	Marginal Wood Fern	5	3	0	1	2	20
	Thelypteris palustris	Marsh Fern	5	-4	0	10	5	20
3	Onoclea sensibilis	Sensitive Fern	4	-3	0	1	1	60
	Carex lacustris	Lake Sedge	5	-5	0		10	40
	Leersia oryzoides	Rice Cutgrass	3	-5	0		7	20
	Carex aquatilis	Water Sedge	7	-5	0		4	40
4	Carex lacustris	Lake Sedge	5	-5	0		30	40
	Scutellaria galericulata	Common Skullcap	6	-5	0	3	2	20
	Poa palustris	Fowl Meadow Grass	5	-4	0		3	20
	Carex aquatilis	Water Sedge	7	-5	0		40	40
5	Dryopteris carthusiana	Spinulose Wood Fern	5	-2	0	1	0.5	40

Sub plot #	Scientific Name	Common Name	CC	CW	Weed	Number/m^2	Cover (%)/m^2	Frequency (%)
Vegetation Plot 005		**FOMM6**	**Fresh-Moist White Cedar Coniferous Forest**					
1	No species in sub-plot							0
2	No species in sub-plot							0
3	Equisetum arvense	Field Horsetail	0	0	0	8	3	20
4	No species in sub-plot							0
5	No species in sub-plot							0

Sub plot #	Scientific Name	Common Name	CC	CW	Weed	Number/m^2	Cover (%)/m^2	Frequency (%)
Vegetation Plot 006		**MAMM1-3**	**Reed-canary Grass Graminoid Mineral Meadow Marsh**					
1	Calamagrostis canadensis	Canada Blue-joint	4	-5	0		2	100
	Juncus tenuis	Path Rush	0	0	0		20	100
	Solidago canadensis	Canada Goldenrod	1	3	0	9	8	100
	Poa pratensis	Kentucky Blue Grass	0	1	0		10	100
	Tussilago farfara	Coltsfoot	*	3	-2	22	15	100
	Phalaris arundinacea	Reed Canary Grass	0	-4	0		20	40
	Equisetum arvense	Field Horsetail	0	0	0	8	5	100
	Festuca arundinacea	Tall Fescue	*	2	-1		1	100
	Taraxacum officinale	Common Dandelion	*	3	-2	6	5	100
	Symphyotrichum lanceolatum	Panicled Aster	3	-3	0	4	2	60
	Juncus effusus	Soft Rush	4	-5	0		1	40
	Carex vulpinoidea	Fox Sedge	3	-5	0	3	1	60
	Epilobium hirsutum	Hairy Willow-Herb	*	-4	-2	1	0.5	100
	Dactylis glomerata	Orchard Grass	*	3	-1		5	80
	Carex blanda	Smooth Sedge	3	0	0		0.5	40
2	Lotus corniculatus	Bird's-foot Trefoil	*	1	-2	6	4	40
	Festuca arundinacea	Tall Fescue	*	2	-1		20	100
	Poa pratensis	Kentucky Blue Grass	0	1	0		5	100
	Epilobium hirsutum	Hairy Willow-Herb	*	-4	-2	4	2	100
	Solidago canadensis	Canada Goldenrod	1	3	0	9	15	100
	Cirsium arvense	Canada Thstle	*	3	-1	2	2	40
	Calamagrostis canadensis	Canada Blue-joint	4	-5	0		1	100
	Taraxacum officinale	Common Dandelion	*	3	-2	6	2	100
	Symphyotrichum lanceolatum	Panicled Aster	3	-3	0	3	1	60
	Tussilago farfara	Coltsfoot	*	3	-2	1	1	100
	Juncus tenuis	Path Rush	0	0	0		5	100
	Mentha arvensis	Common Mint	3	-3	0	2	1	20
	Lycopus americanus	American Water-horehound	4	-5	0	2	1	20
	Medicago lupulina	Black Medick	*	1	-1	1	0.5	60
	Equisetum arvense	Field Horsetail	0	0	0	1	0.5	100

3	Taraxacum officinale	Common Dandelion	*	3	-2	13	10	100
	Dactylis glomerata	Orchard Grass	*	3	-1		3	80
	Poa pratensis	Kentucky Blue Grass	0	1	0		1	100
	Juncus tenuis	Path Rush	0	0	0		5	100
	Calamagrostis canadensis	Canada Blue-joint	4	-5	0		2	100
	Tussilago farfara	Coltsfoot	*	3	-2	17	20	100
	Epilobium hirsutum	Hairy Willow-Herb	*	-4	-2	3	1	100
	Juncus effusus	Soft Rush	4	-5	0		0.5	40
	Festuca arundinacea	Tall Fescue	*	2	-1		8	100
	Solidago canadensis	Canada Goldenrod	1	3	0	14	20	100
	Equisetum arvense	Field Horsetail	0	0	0	1	0.5	100
	Daucus carota	Queen Anne's Lace	*	5	-2	1	0.5	40
	Phalaris arundinacea	Reed Canary Grass	0	-4	0		1	40
	Carex vulpinoidea	Fox Sedge	3	-5	0		0.5	60
4	Festuca arundinacea	Tall Fescue	*	2	-1		10	100
	Solidago canadensis	Canada Goldenrod	1	3	0	19	30	100
	Poa pratensis	Kentucky Blue Grass	0	1	0		5	100
	Calamagrostis canadensis	Canada Blue-joint	4	-5	0		3	100
	Lotus corniculatus	Bird's-foot Trefoil	*	1	-2	6	3	40
	Tussilago farfara	Coltsfoot	*	3	-2	15	15	100
	Juncus tenuis	Path Rush	0	0	0		2	100
	Taraxacum officinale	Common Dandelion	*	3	-2	5	3	100
	Medicago lupulina	Black Medick	*	1	-1	3	1	60
	Cirsium arvense	Canada Thstle	*	3	-1	1	1	40
	Geum aleppicum	Yellow Avens	2	-1	0	2	1	20
	Dactylis glomerata	Orchard Grass	*	3	-1		3	80
	Epilobium hirsutum	Hairy Willow-Herb	*	-4	-2	5	1	100
	Equisetum arvense	Field Horsetail	0	0	0	2	1	100
5	Carex flava	Yellow Sedge	5	-5	0		0.5	20
	Solidago canadensis	Canada Goldenrod	1	3	0	16	8	100
	Solidago altissima	Tall Goldenrod	1	3	0	3	3	20
	Dactylis glomerata	Orchard Grass	*	3	-1		10	80
	Tussilago farfara	Coltsfoot	*	3	-2	20	15	100
	Festuca arundinacea	Tall Fescue	*	2	-1		6	100
	Daucus carota	Queen Anne's Lace	*	5	-2	1	0.5	40
	Epilobium hirsutum	Hairy Willow-Herb	*	-4	-2	1	1	100
	Cerastium fontanum	Mouse-eared Chickweed	*	3	-1	5	2	20
	Taraxacum officinale	Common Dandelion	*	3	-2	2	1	100
	Equisetum arvense	Field Horsetail	0	0	0	1	0.5	100
	Medicago lupulina	Black Medick	*	1	-1	2	0.5	60
	Carex vulpinoidea	Fox Sedge	3	-5	0		2	60
	Poa pratensis	Kentucky Blue Grass	0	1	0		4	100
	Calamagrostis canadensis	Canada Blue-joint	4	-5	0		2	100
	Carex stricta	Tussock Sedge	4	-5	0		0.5	20
	Symphyotrichum lanceolatum	Panicled Aster	3	-3	0	1	1	60
	Euthamia graminifolia	Grass-leaved Goldenrod	2	-2	0	1	1	20
	Carex blanda	Smooth Sedge	3	0	0		1	40
	Juncus tenuis	Path Rush	0	0	0		3	100

Sub plot #	Scientific Name	Common Name	CC	CW	Weed	Number/m^2	Cover (%)/m^2	Frequency (%)
Vegetation Plot 007		**SWMM1-1**	**White Cedar - Hardwood Mineral Mixed Swamp**					
1	Carex laxiflora	Loose-flowered Sedge	5	0	0		2	80
	Aralia nudicaulis	Wild Sarsaparilla	4	3	0	2	5	80
	Geum var	Avens species				1	0.5	20
2	Cystopteris bulbifera	Bulblet fern	5	-2	0	2	4	80
	Prunella vulgaris ssp. lanceolata	Selfheal	5	5	0	5	3	20
	Cicuta maculata	Spotted Water Hemlock	6	-5	0	3	5	20
	Carex laxiflora	Loose-flowered Sedge	5	0	0	1	0.5	80
	Fragaria vesca	Woodland Strawberry	4	4	0	1	0.1	20
	Impatiens capensis	Spotted Jewelweed	4	-3	0	1	0.5	60
	Mitella nuda	Naked Miterwort	6	-3	0	2	0.5	40
	Arisaema triphyllum	Jack-in-the-pulpit	5	-2	0	1	0.1	20
3	Aralia nudicaulis	Wild Sarsaparilla	4	3	0	10	12	80
	Impatiens capensis	Spotted Jewelweed	4	-3	0	13	3	60
	Trientalis borealis	Starflower	6	-1	0	6	1	60
	Cystopteris bulbifera	Bulblet Fern	5	-2	0	3	2	80
	Dryopteris carthusiana	Spinulose Wood Fern	5	-2	0	1	1	40
	Scutellaria galericulata	Common Skullcap	6	-5	0	1	0.1	20
	Mitella nuda	Naked Miterwort	6	-3	0	1	0.1	40
	Osmunda cinnamomea	Cinnamon Fern	7	-3	0	1	0.5	20
4	Aralia nudicaulis	Wild Sarsaparilla	4	3	0	7	6	80
	Carex spp.	Sedge species	0	0	0		1	20
	Carex laxiflora	Loose-flowered Sedge	5	0	0		0.5	80
	Trientalis borealis	Starflower	6	-1	0	4	0.5	60
	Impatiens capensis	Spotted Jewelweed	4	-3	0	2	0.5	60
	Cystopteris bulbifera	Bulblet Fern	5	-2	0	1	0.5	80
5	Aralia nudicaulis	Wild Sarsaparilla	4	3	0	14	40	80
	Maianthemum canadense	Canada Mayflower	5	0	0	10	1	20
	Trientalis borealis	Starflower	6	-1	0	3	0.5	60
	Cystopteris bulbifera	Bulblet Fern	5	-2	0	1	0.5	80
	Dryopteris carthusiana	Spinulose Wood Fern	5	-2	0	3	1	40
	Carex laxiflora	Loose-flowered Sedge	5	0	0		2	80

Sub plot #	Scientific Name	Common Name	CC	CW	Weed	Number/m^2	Cover (%)/m^2	Frequency (%)
Vegetation Plot 008		**SWMM1-1**	**White Cedar - Hardwood Mineral Mixed Swamp**					
1	Carex lacustris	Lake Sedge	5	-5	0		3	20
	Nasturtium officinale	Watercress	*	-5	-1	50	20	40
	Bidens frondosa	Devil's beggarticks	3	-3	0	1	1	20
	Tussilago farfara	Coltsfoot	*	3	-2	2	0.5	60
	Mentha arvensis	Common Mint	3	-3	0	3	1	20
	Glyceria striata	Fowl Manna Grass	3	-5	0		2	20
	Polygonum var					1	1	0
2	No species in sub-plot					1		0
3	Tussilago farfara	Coltsfoot	*	3	-2	8	6	60
	Cystopteris bulbifera	Bulblet Fern	5	-2	0	3	2	20
4	Tussilago farfara	Coltsfoot	*	3	-2	1	2	60
5	Ranunculus repens	Creeping Buttercup	0	-1	-1	15	20	20
	Nasturtium officinale	Watercress	*	-5	-1	30	15	40

Sub plot #	Scientific Name	Common Name	CC	CW	Weed	Number/m^2	Cover (%)/m^2	Frequency (%)
Vegetation Plot 009		**MASM1-1**	**Cattail Mineral Shallow Marsh**					
1	Eupatorium maculatum	Spotted Joe-Pye Weed	3	-5	0	1	3	40
	Phalaris arundinacea	Reed Canary Grass	0	-4	0		40	100
	Equisetum arvense	Field Horsetail	0	0	0	2	2	60
	Typha angustifolia	Narrow-leaved Cattail	3	-5	0		50	60
2	Phalaris arundinacea	Reed Canary Grass	0	-4	0		60	100
	Typha angustifolia	Narrow-leaved Cattail	3	-5	0		35	60
	Equisetum arvense	Field Horsetail	0	0	0	3	2	60
3	Phalaris arundinacea	Reed Canary Grass	0	-4	0		60	100
	Typha angustifolia	Narrow-leaved Cattail	3	-5	0		35	60
	Equisetum arvense	Field Horsetail	0	0	0	1	1	60
4	Phalaris arundinacea	Reed Canary Grass	0	-4	0		80	100
	Typha latifolia	Cattail	3	-5	0		10	40
	Eupatorium maculatum	Spotted Joe-Pye Weed	3	-5	0	1	2	40
	Symphyotrichum lanceolatum	Panicled Aster	3	-3	0	1	2	20
	Lysimachia ciliata	Fringed Loosestrife	4	-3	0	2	1	20
5	Phalaris arundinacea	Reed Canary Grass	0	-4	0		80	100
	Typha latifolia	Cattail	3	-5	0		10	40
	Solidago canadensis	Canada Goldenrod	1	3	0	3	3	20
	Mentha arvensis	Common Mint	3	-3	0	1	1	20
	Symphyotrichum puniceum	Purple Stemmed Aster	6	-5	0	4	5	20

Sub plot #	Scientific Name	Common Name	CC	CW	Weed	Number/m^2	Cover (%)/m^2	Frequency (%)
Vegetation Plot 016		**SWDM3-2**	**Silver Maple Mineral Deciduous Swamp**					
1	Onoclea sensibilis	Sensitive Fern	4	-3	0	8	2	40
	Carex lupulina	Hop Sedge	6	-5	0		2	40
2	No species in sub-plot							0
3	No species in sub-plot							0
4	Onoclea sensibilis	Sensitive Fern	4	-3	0	1	1	40
	Phalaris arundinacea	Reed Canary Grass	0	-4	0		1	20
5	Carex lupulina	Hop Sedge	6	-5	0		1	40
	Thelypteris palustris	Marsh Fern	5	-4	0	2	1	20

Sub plot #	Scientific Name	Common Name	CC	CW	Weed	Number/m^2	Cover (%)/m^2	Frequency (%)
Vegetation Plot 018		**SWDO2-2**	**Silver Maple Organic Deciduous Swamp**					
1	Caltha palustris	Marsh Marigold	5	-5	0	8	25	80
	Taraxacum officinale	Common Dandelion	*	3	-2	1	0.5	40
	Glyceria striata	Fowl Manna Grass	3	-5	0		1	60
2	Onoclea sensibilis	Sensitive Fern	4	-3	0	20	70	80
	Solidago gigantea	Late Goldenrod	4	-3	0	10	15	40
	Caltha palustris	Marsh Marigold	5	-5	0	3	5	80
	Echinocystis lobata	Wild Cucumber	3	-2	0	1	3	20
	Symphyotrichum lanceolatum	Panicled Aster	3	-3	0	1	1	60
	Mentha arvensis	Common Mint	3	-3	0	1	0.5	40
	Equisetum arvense	Field Horsetail	0	0	0	2	1	80
	Daucus carota	Queen Anne's Lace	*	5	-2	1	0.5	20
3	Onoclea sensibilis	Sensitive Fern	4	-3	0	10	50	80
	Glyceria striata	Fowl Manna Grass	3	-5	0		65	60
	Galium palustre	Marsh Bedstraw	5	-5	0	6	5	40
	Caltha palustris	Marsh Marigold	5	-5	0	2	5	80
	Mentha arvensis	Common Mint	3	-3	0	1	1	40
	Equisetum arvense	Field Horsetail	0	0	0	3	3	80
	Symphyotrichum lanceolatum	Panicled Aster	3	-3	0	1	1	60
	Symphyotrichum puniceum	Purple Stemmed Aster	6	-5	0	1	2	40
4	Onoclea sensibilis	Sensitive Fern	4	-3	0	6	35	80
	Glyceria striata	Fowl Manna Grass	3	-5	0		5	60
	Caltha palustris	Marsh Marigold	5	-5	0	15	20	80
	Galium palustre	Marsh Bedstraw	5	-5	0	2	2	40
	Equisetum arvense	Field Horsetail	0	0	0	3	5	80
5	Solidago rugosa	Rough-stemmed Goldenrod	4	-1	0	7	7	20
	Lycopus uniflorus	Northern Bugleweed	5	-5	0	6	4	20
	Symphyotrichum lanceolatum	Panicled Aster	3	-3	0	11	15	60
	Symphyotrichum puniceum	Purple Stemmed Aster	6	-5	0	2	2	40
	Taraxacum officinale	Common Dandelion	*	3	-2	2	1	40
	Onoclea sensibilis	Sensitive Fern	4	-3	0	15	30	80
	Impatiens capensis	Spotted Jewelweed	4	-3	0	2	1	20
	Polygonatum pubescens	Hairy Solomon's Seal	5	5	0	7	10	20
	Equisetum arvense	Field Horsetail	0	0	0	3	3	80
	Dryopteris carthusiana	Spinulose Wood Fern	5	-2	0	3	1	20
	Solidago gigantea	Late Goldenrod	4	-3	0	1	1	40

APPENDIX III

Herbaceous Species Observed by Subplot 2006 - 2014

Appendix III. Herbaceous Species Observed by Sub-Plot (2006 - 2014)

Plot #	Sub plot #	Scientific Name	Common Name	2006	2007	2008	2009	2010	2011	2012	2013	2014
VEG-001	1	*Asclepias incarnata*	Swamp Milkweed								√	√
		Aster spp.	Aster species		√	√	√					
		Calamagrostis canadensis	Canada Blue-joint		√	√	√	√	√		√	√
		Carex aquatilis	Water Sedge				√		√	√	√	√
		Carex lacustris	Lake Sedge	√								
		Carex stipata	Awl-fruited Sedge			√		√				
		Cicuta bulbifera	Bulbous Water-hemlock						√			
		Cirsium arvense	Canada Thistle	√								
		Epilobium species	Willow-Herb species								√	√
		Equisetum arvense	Field Horsetail		√	√					√	√
		Equisetum pratense	Meadow Horsetail	√						√		
		Galium palustre	Marsh Bedstraw								√	√
		Impatiens capensis	Spotted Jewelweed		√	√	√	√	√	√	√	√
		Lycopus uniflorus	Northern Bugleweed					√	√			
		Lysimachia thrysiflora	Tufted Loosestrife					√	√			
		Phalaris arundinacea	Reed Canary Grass							√		
		Poa palustris	Fowl Meadow Grass								√	√
		Poa spp.	Grass species	√								
		Scutellaria galericulata	Common Skullcap							√		
		Solidago canadensis	Canada Goldenrod	√								
		Solidago spp.	Goldenrod species			√						
		Symphyotrichum lanceolatum	Panicled Aster							√		
		Symphyotrichum novae-angliae	New England Aster							√		
		Veronica spp.	Speedwell species				√					
			Moss species		√				√			
	2	*Asclepias incarnata*	Swamp Milkweed								√	√
		Calamagrostis canadensis	Canada Blue-joint	√	√							
		Carex aquatilis	Water Sedge				√		√	√	√	√
		Carex lacustris	Lake Sedge			√	√					
		Carex stipata	Awl-fruited Sedge	√	√							
		Carex utriculata	Beaked Sedge		√							
		Cicuta bulbifera	Bulbous Water-hemlock					√	√	√		
		Epilobium hirsutum	Hairy Willow-Herb							√	√	√
		Epilobium leptophyllum	Narrow-leaved Willow-herb					√				
		Equisetum arvense	Field Horsetail		√						√	√
		Equisetum pratense	Meadow Horsetail	√						√		
		Galium palustre	Marsh Bedstraw			√		√			√	√
		Impatiens capensis	Spotted Jewelweed	√	√	√		√		√	√	√
		Juncus spp.	Rush species	√								
		Lemna spp.	Duckweed species				√					
		Lycopus uniflorus	Northern Bugleweed			√		√	√			
		Lysimachia thrysiflora	Tufted Loosestrife					√		√		
		Lythrum salicaria	Purple Loosestrife							√		
		Phalaris arundinacea	Reed Canary Grass						√	√		
		Poa spp.	Grass species	√				√				
		Sium suave	Water Parsnip								√	√
		Solanum dulcamara	Bittersweet Nightshade	√								
		Solidago canadensis	Canada Goldenrod	√								
			Moss species					√		√		
	3	*Aster spp.*	Aster species				√					
		Bidens frondosa	Devil's Beggarticks							√		
		Calamagrostis canadensis	Canada Blue-joint	√	√							
		Carex aquatilis	Water Sedge						√		√	√
		Carex lacustris	Lake Sedge	√		√	√				√	√
		Carex stipata	Awl-fruited Sedge	√								
		Carex utriculata	Beaked Sedge		√							
		Carex vulpinoidea	Fox Sedge								√	√
		Cicuta bulbifera	Bulbous Water-hemlock							√		
		Cirsium var	Thistle species							√		
		Epilobium hirsutum	Hairy Willow-Herb							√		
		Equisetum arvense	Field Horsetail								√	√
		Equisetum pratense	Meadow Horsetail	√								
		Galium palustre	Marsh Bedstraw							√	√	√
		Impatiens capensis	Spotted Jewelweed	√	√	√				√	√	√
		Lycopus americanus	American Water-horehound								√	√
		Lycopus uniflorus	Northern Bugleweed		√			√		√		
		Lysimachia terrestris	Swamp Candles							√		
		Lysimachia thrysiflora	Tufted Loosestrife		√							
		Phalaris arundinacea	Reed Canary Grass					√	√	√		
		Poa spp.	Grass species	√								
		Scutellaria galericulata	Common Skullcap							√		
		Sium suave	Water Parsnip		√						√	√
		Solidago canadensis	Canada Goldenrod	√							√	√
		Solidago spp.	Goldenrod species				√					
		Spirodela polyrhiza	Duckweed					√				
		Symphyotrichum lanceolatum	Panicled Aster							√		
		Symphyotrichum puniceum	Purple Stemmed Aster								√	√
	4	*Asclepias incarnata*	Swamp Milkweed		√							
		Bidens frondosa	Devil's Beggarticks							√		
		Calamagrostis canadensis	Canada Blue-joint	√	√							
		Carex aquatilis	Water Sedge							√	√	√
		Carex lacustris	Lake Sedge			√	√	√	√		√	√
		Carex stipata	Awl-fruited Sedge	√	√							
		Cicuta bulbifera	Bulbous Water-hemlock							√		
		Dryopteris cristata	Crested Wood Fern								√	√
		Epilobium hirsutum	Hairy Willow-Herb							√		
		Equisetum arvense	Field Horsetail						√			

Plot #	Sub plot #	Scientific Name	Common Name	2006	2007	2008	2009	2010	2011	2012	2013	2014
		Galium palustre	Marsh Bedstraw					√		√	√	√
		Impatiens capensis	Spotted Jewelweed	√	√			√		√	√	√
		Leersia oryzoides	Rice Cutgrass	√								
		Lycopus uniflorus	Northern Bugleweed		√			√	√	√		
		Lysimachia terrestris	Swamp Candles								√	√
		Lysimachia thrysiflora	Tufted Loosestrife						√			
		Lythraceae	Loosestrife species									
		Scutellaria galericulata	Common Skullcap	√						√		
		Sium suave	Water Parsnip			√		√				
		Spirodela polyrhiza	Duckweed					√				
		Symphyotrichum lanceolatum	Panicled Aster								√	√
		Symphyotrichum novae-angliae	New England Aster							√		
			Moss species							√		
	5	*Asclepias incarnata*	Swamp Milkweed								√	√
		Aster spp.	Aster species		√							
		Calamagrostis canadensis	Canada Blue-joint	√	√	√	√	√	√			
		Carex aquatilis	Water Sedge				√			√	√	√
		Carex lacustris	Lake Sedge		√				√			
		Carex stipata	Awl-fruited Sedge	√	√	√	√	√	√			
		Carex stricta	Stiff Sedge		√							
		Cirsium arvense	Canada Thistle	√								
		Equisetum arvense	Field Horsetail		√	√					√	√
		Equisetum palustre	Marsh Horsetail						√			
		Impatiens capensis	Spotted Jewelweed		√	√	√	√	√	√	√	√
		Lycopus americanus	American Water-horehound								√	√
		Lysimachia terrestris	Swamp Candles							√		
		Lysimachia thrysiflora	Tufted Loosestrife					√	√			
		Phalaris arundinacea	Reed Canary Grass							√	√	√
		Sium suave	Water Parsnip								√	√
		Solidago altissima	Tall Goldenrod							√		
		Solidago canadensis	Canada Goldenrod	√								
		Solidago spp.	Goldenrod species		√							
		Symphyotrichum lanceolatum	Panicled Aster							√		

Plot #	Sub plot #	Scientific Name	Common Name	2006	2007	2008	2009	2010	2011	2012	2013	2014
VEG-002	1	*Aster spp.*	Aster species		√							
		Caltha palustris	Marsh Marigold	√		√	√	√	√	√	√	√
		Circaea lutetiana ssp. canadensis	Yellowish Enchanter's Nightshade								√	√
		Circaea quadrisulcata	Enchanter's Nightshade							√		
		Cirsium var	Thistle species							√	√	√
		Epilobium hirsutum	Hairy Willow-Herb							√	√	√
		Equisetum arvense	Field Horsetail								√	√
		Equisetum palustre	Marsh Horsetail		√			√				
		Lycopus uniflorus	Northern Bugleweed					√	√	√		
		Scutellaria galericulata	Common Skullcap							√		
		Solidago canadensis	Canada Goldenrod								√	√
		Symphyotrichum novae-angliae	New England Aster								√	√
			Moss species	√		√						
	2	*Caltha palustris*	Marsh Marigold	√				√	√			
		Cirsium var	Thistle species							√	√	√
		Cysptopteris tenuis	Mackay's Fragile Fern		√							
		Dryopteris carthusiana	Spinulose Wood Fern								√	√
		Epipactis helleborine	Helleborine				√					
		Equisetum pratense	Meadow Horsetail	√				√		√		
		Fragaria vesca	Woodland Strawberry	√								
		Impatiens capensis	Spotted Jewelweed								√	√
		Lycopus uniflorus	Northern Bugleweed	√								
		Maianthemum canadense	Wild Lily-of-the-Valley	√	√	√	√			√		
		Onoclea sensibilis	Sensitive Fern					√	√			
		Poa spp.	Grass species		√							
		Solidago spp.	Goldenrod species		√			√				
		Taraxacum officinale	Common Dandelion		√	√				√		
		Thelypteris palustris	Marsh Fern					√				
			Moss species	√	√		√			√		
	3	*Caltha palustris*	Marsh Marigold	√	√		√	√		√		
		Cirsium muticum	Swamp Thistle								√	√
		Cirsium var	Thistle species							√		
		Epilobium hirsutum	Hairy Willow-Herb							√		
		Equisetum pratense	Meadow Horsetail	√								
		Eupatorium perfoliatum	Boneset								√	√
		Impatiens capensis	Spotted Jewelweed							√	√	√
		Lycopus uniflorus	Northern Bugleweed	√								
		Mitella nuda	Naked Miterwort							√		
		Pilea pumila	Clearweed								√	√
		Scutellaria lateriflora	Mad-dog Skullcap							√		
			Moss species	√	√					√		
	4	*Caltha palustris*	Marsh Marigold		√	√		√				
		Epilobium hirsutum	Hairy Willow-Herb							√		
		Erigeron var	Fleabane species							√		
		Impatiens capensis	Spotted Jewelweed							√	√	√
		Maianthemum canadense	Canada Mayflower						√			
		Poa spp.	Grass species						√			
		Scutellaria lateriflora	Mad-dog Skullcap							√		
		Taraxacum officinale	Common Dandelion							√		
			Moss species		√				√			
	5	*Arctium var*	Burdock species							√		
		Bidens frondosa	Devil's Beggarticks							√		
		Caltha palustris	Marsh Marigold	√	√	√	√	√	√		√	√
		Cirsium arvense	canada thistle								√	
		Cirsium var	Thistle species							√		√
		Dryopteris carthusiana	Spinulose Wood Fern		√							
		Eupatorium perfoliatum	Boneset								√	√
		Impatiens capensis	Spotted Jewelweed							√	√	√
		Lycopus americanus	American Water-horehound								√	√
		Lycopus uniflorus	Northern Bugleweed		√							
		Maianthemum canadense	Canada Mayflower	√		√		√	√			
		Solidago spp.	Goldenrod species								√	√
		Taraxacum officinale	Common Dandelion		√				√			
			Moss species	√	√	√		√	√	√		

Plot #	Sub plot #	Scientific Name	Common Name	2006	2007	2008	2009	2010	2011	2012	2013	2014
VEG-003	1	*Arisaema triphyllum*	Jack-in-the-pulpit				√	√	√			
		Circaea lutetiana ssp. canadensis	Yellowish Enchanter's Nightshade								√	√
		Circaea quadrisulcata	Enchanter's Nightshade						√			
		Matteuccia struthiopteris	American Ostrich Fern	√	√	√	√	√	√	√	√	√
		Solanum dulcamara	Bittersweet Nightshade	√								
		Solidago canadensis	Canada Goldenrod						√			
		Solidago flexicaulis	Zig-zag goldenrod						√			
		Taraxacum officinale	Common Dandelion						√	√		
		Thelypteris palustris	Marsh Fern			√						
		Trillium var	Trillium species								√	√
			Moss species	√			√		√	√		
	2	*Arisaema triphyllum*	Jack-in-the-pulpit						√			
		Dryopteris marginalis	Marginal Wood Fern							√		
		Matteuccia struthiopteris	American Ostrich Fern	√	√	√	√	√	√	√	√	√
		Taraxacum officinale	Common Dandelion							√		
			Moss species	√					√	√		
	3	*Arisaema triphyllum*	Jack-in-the-pulpit				√	√		√		
		Circaea quadrisulcata	Enchanter's Nightshade							√		
		Dryopteris cristata	Crested Wood Fern						√			
		Dryopteris marginalis	Marginal Wood Fern				√					
		Matteuccia struthiopteris	American Ostrich Fern	√	√	√	√		√	√	√	√
		Taraxacum officinale	Common Dandelion							√		
	4	*Arisaema triphyllum*	Jack-in-the-pulpit				√			√		
		Dryopteris clintoniana	Clinton's Wood Fern		√							
		Dryopteris marginalis	Marginal Wood Fern				√			√		
		Matteuccia struthiopteris	American Ostrich Fern	√	√	√	√	√	√	√	√	√
		Taraxacum officinale	Common Dandelion							√		
	5	*Arisaema triphyllum*	Jack-in-the-pulpit				√		√			
		Dryopteris clintoniana	Clinton's Wood Fern		√							
		Matteuccia struthiopteris	American Ostrich Fern	√	√	√	√	√	√	√	√	√
		Trillium var	Trillium species								√	√
			Moss species				√					

Plot #	Sub plot #	Scientific Name	Common Name	2006	2007	2008	2009	2010	2011	2012	2013	2014
VEG-004	1	*Dryopteris clintoniana*	Clinton's Wood Fern		√							
		Dryopteris cristata	Crested Wood Fern					√				
		Onoclea sensibilis	Sensitive Fern								√	√
		Parthenocissus quinquefolia	Virginia Creeper	√								
			Moss species				√	√		√		
	2	*Cicuta maculata*	Spotted Water hemlock		√							
		Circaea quadrisulcata	Enchanter's Nightshade		√			√				
		Cystopteris bulbifera	Bulblet Fern		√							
		Dryopteris carthusiana	Spinulose Wood Fern			√				√	√	√
		Dryopteris marginalis	Marginal Wood Fern								√	√
		Equisetum arvense	Field Horsetail		√							
		Equisetum pratense	Meadow Horsetail	√								
		Galium palustre	Marsh Bedstraw		√							
		Maianthemum canadense	Wild Lily-of-the-Valley			√				√		
		Onoclea sensibilis	Sensitive Fern	√	√	√		√	√	√	√	√
		Pilea pumila	Clearweed			√						
		Scirpus americanus	Common Three Square		√							
		Scutellaria lateriflora	Mad-dog Skullcap	√								
		Thelypteris palustris	Marsh Fern								√	√
			Moss species		√	√	√	√		√		
	3	*Carex aquatilis*	Water Sedge								√	√
		Carex lacustris	Lake Sedge								√	√
		Cystopteris bulbifera	Bulblet Fern		√							
		Dryopteris carthusiana	Spinulose Wood Fern	√				√	√	√		
		Dryopteris cristata	Crested Wood Fern			√	√	√	√			
		Dryopteris marginalis	Marginal Wood Fern							√		
		Equisetum arvense	Field Horsetail		√							
		Equisetum pratense	Meadow Horsetail	√			√					
		Galium palustre	Marsh Bedstraw		√							
		Impatiens capensis	Spotted Jewelweed		√							
		Leersia oryzoides	Rice Cutgrass								√	√
		Lysimachia terrestris	Swamp Candles						√			
		Maianthemum canadense	Canada Mayflower				√					
		Onoclea sensibilis	Sensitive Fern	√	√	√	√	√	√	√	√	√
		Poa spp.	Grass species	√		√	√	√				
		Scirpus americanus	Common Three Square	√	√							
		Taraxacum officinale	Common Dandelion				√					
		Thelypteris palustris	Marsh Fern	√		√	√			√		
		Tiarella cordifolia	Foam Flower		√							
	4	*Carex aquatilis*	Water Sedge				√			√	√	√
		Carex lacustris	Lake Sedge			√	√	√	√	√	√	√
		Cicuta maculata	Spotted Water hemlock		√				√			
		Dryopteris carthusiana	Spinulose Wood Fern	√					√	√		
		Dryopteris clintoniana	Clinton's Wood Fern		√							
		Dryopteris cristata	Crested Wood Fern			√		√				
		Equisetum arvense	Field Horsetail		√	√						
		Equisetum pratense	Meadow Horsetail	√			√					
		Eupatorium maculatum	Spotted Joe-Pye Weed	√								
		Galium palustre	Marsh Bedstraw	√	√	√	√	√	√	√		
		Impatiens capensis	Spotted Jewelweed		√		√	√		√		
		Leersia oryzoides	Rice Cutgrass							√		
		Lycopus uniflorus	Northern Bugleweed	√		√	√	√		√		
		Lysimachia terrestris	Swamp Candles		√							
		Onoclea sensibilis	Sensitive Fern	√	√	√	√	√		√		
		Parthenocissus quinquefolia	Virginia Creeper	√		√						
		Poa palustris	Fowl Meadow Grass								√	√
		Poa spp.	Grass species		√	√		√		√		
		Ranunculus var	Buttercup species						√			
		Rubus pubescens	Dwarf Raspberry					√				
		Scirpus americanus	Common Three Square	√	√	√						
		Scutellaria galericulata	Common Skullcap			√	√			√	√	√
		Scutellaria lateriflora	Mad-dog Skullcap							√		
		Solidago rugosa	Rough-stemmed Goldenrod							√		
		Solanum dulcamara	Bittersweet Nightshade			√						
		Symphyotrichum racemosum	Small White Aster					√				
		Taraxacum officinale	Common Dandelion	√								
		Thelypteris noveboracensis	New York Fern		√							
		Thelypteris palustris	Marsh Fern	√		√	√			√		
		Veronica scutellata	Marsh Speedwell	√				√				
			Moss species	√	√	√	√	√				
	5	*Dryopteris carthusiana*	Spinulose Wood Fern						√		√	√
		Onoclea sensibilis	Sensitive Fern						√			
		Thelypteris palustris	Marsh Fern							√		

Plot #	Sub plot #	Scientific Name	Common Name	2006	2007	2008	2009	2010	2011	2012	2013	2014
VEG-005	1	*Arisaema triphyllum*	Jack-in-the-pulpit		√							
		Athyrium filix-femina	Northeastern Lady Fern		√							
		Equisetum pratense	Meadow Horsetail	√	√		√	√		√		
	2	*Equisetum arvense*	Field Horsetail		√	√		√				
		Equisetum pratense	Meadow Horsetail							√		
		Maianthemum canadense	Wild Lily-of-the-Valley		√	√						
			Moss species	√	√	√	√	√		√		
	3	*Equisetum arvense*	Field Horsetail		√						√	√
		Equisetum pratense	Meadow Horsetail	√				√		√		
			Moss species	√	√	√	√	√				
		Equisetum pratense	Meadow Horsetail									
	4	*Equisetum arvense*	Field Horsetail		√	√						
		Equisetum pratense	Meadow Horsetail	√			√			√		
		Maianthemum canadense	Canada Mayflower				√					
		Poa spp.	Grass species				√					
			Moss species	√						√		
		Equisetum pratense	Meadow Horsetail									
	5		Moss species	√	√		√			√		

Plot #	Sub plot #	Scientific Name	Common Name	2006	2007	2008	2009	2010	2011	2012	2013	2014
VEG-006	1	*Bromus inermis ssp. inermis*	Smooth Brome						√			
		Calamagrostis canadensis	Canada Blue-joint								√	√
		Carex blanda	Smooth Sedge								√	√
		Carex stipata	Awl-fruited Sedge					√				
		Carex vulpinoidea	Fox Sedge		√		√		√	√	√	√
		Cirsium arvense	Canada Thistle	√	√				√	√		
		Dactylis glomerata	Orchard Grass							√	√	√
		Daucus carota	Queen Anne's Lace						√			
		Echinochloa crusgalli	Barnyard Grass				√	√				
		Epilobium hirsutum	Hairy Willow-Herb					√			√	√
		Equisetum arvense	Field Horsetail		√	√	√		√		√	√
		Equisetum pratense	Meadow Horsetail							√		
		Euthamia graminifolia	Grass-leaved Goldenrod				√	√	√	√		
		Festuca arundinacea	Tall Fescue								√	√
		Juncus effusus	Soft Rush								√	√
		Juncus tenuis	Path Rush	√					√	√	√	√
		Lotus corniculatus	Bird's-foot Trefoil		√		√	√				
		Mentha arvensis	Common Mint					√				
		Phalaris arundinacea	Reed Canary Grass								√	√
		Phleum pratense	Timothy							√		
		Poa pratensis	Kentucky Blue Grass			√		√		√	√	√
		Poa spp.	Grass species	√	√							
		Scirpus atrovirens	Dark Green Bulrush						√			
		Solidago altissima	Tall Goldenrod	√					√	√		
		Solidago canadensis	Canada Goldenrod	√	√	√	√	√	√		√	√
		Symphyotrichum lanceolatum	Panicled Aster			√				√	√	√
		Symphyotrichum novae-angliae	New England Aster		√							
		Symphyotrichum puniceum	Purple Stemmed Aster		√							
		Taraxacum officinale	Common Dandelion						√		√	
		Tussilago farfara	Coltsfoot	√	√	√	√	√	√	√	√	√
	2	*Bromus inermis ssp. inermis*	Smooth Brome						√			
		Calamagrostis canadensis	Canada Blue-joint								√	√
		Carex stipata	Awl-fruited Sedge	√								
		Carex trisperma var. trisperma	Three-seeded Sedge		√							
		Carex vulpinoidea	Fox Sedge				√	√	√	√		
		Cirsium arvense	Canada Thistle	√	√	√	√				√	√
		Daucus carota	Queen Anne's Lace					√		√		
		Drepanocladus spp.	Sickle Moss						√			
		Echinochloa crusgalli	Barnyard Grass				√	√				
		Epilobium hirsutum	Hairy Willow-Herb					√	√	√	√	√
		Equisetum arvense	Field Horsetail		√	√			√		√	√
		Equisetum pratense	Meadow Horsetail							√		
		Euthamia graminifolia	Grass-leaved Goldenrod				√	√	√	√		
		Festuca arundinacea	Tall Fescue								√	√
		Galium palustre	Marsh Bedstraw				√					
		Hieracium pratense	King Devil Hawkweed			√						
		Juncus tenuis	Path Rush				√	√	√	√	√	√
		Lactuca serriola	Prickly Lettuce	√								
		Lotus corniculatus	Bird's-foot Trefoil			√		√		√	√	√
		Lycopus americanus	American Water-horehound								√	√
		Medicago lupulina	Black Medick					√	√		√	√
		Mentha arvensis	Common Mint			√		√	√	√	√	√
		Phalaris arundinacea	Reed Canary Grass				√					
		Plantago major	Common Plantain						√			
		Poa pratensis	Kentucky Blue Grass		√	√					√	√
		Poa spp.	Grass species	√								
		Potentilla recta	Sulphur Cinquefoil							√		
		Scirpus atrovirens	Dark Green Bulrush						√	√		
		Solidago altissima	Tall Goldenrod	√						√		
		Solidago canadensis	Canada Goldenrod			√			√		√	√
		Symphyotrichum lanceolatum	Panicled Aster			√				√	√	√
		Symphyotrichum novae-angliae	New England Aster			√				√		
		Symphyotrichum puniceum	Purple Stemmed Aster		√				√			
		Taraxacum officinale	Common Dandelion	√	√		√		√	√	√	√
		Trifolium hybridum	Alsike Clover					√				
		Trifolium repens	White Clover					√				
		Tussilago farfara	Coltsfoot	√	√	√	√	√	√		√	√
		Waldsteinia fragarioides	Barren Strawberry		√							
			Moss species		√							
	3	*Bromus inermis ssp. inermis*	Smooth Brome						√			
		Calamagrostis canadensis	Canada Blue-joint								√	√
		Carex stipata	Awl-fruited Sedge	√								
		Carex stricta	Stiff Sedge			√						
		Carex vulpinoidea	Fox Sedge			√		√			√	√
		Cirsium arvense	Canada Thistle	√	√					√		
		Dactylis glomerata	Orchard Grass								√	√
		Daucus carota	Queen Anne's Lace								√	√
		Echinochloa crusgalli	Barnyard Grass				√	√				
		Eleocharis smallii	Small's Spike-Rush					√				
		Epilobium hirsutum	Hairy Willow-Herb				√	√			√	√
		Equisetum arvense	Field Horsetail		√	√	√		√		√	√
		Equisetum pratense	Meadow Horsetail	√								
		Euthamia graminifolia	Grass-leaved Goldenrod			√	√	√	√			
		Festuca arundinacea	Tall Fescue								√	√
		Galium palustre	Marsh Bedstraw						√			
		Geum aleppicum	Yellow Avens						√	√		
		Juncus effusus	Soft Rush								√	√

Plot #	Sub plot #	Scientific Name	Common Name	2006	2007	2008	2009	2010	2011	2012	2013	2014
		Juncus tenuis	Path Rush				√	√	√	√	√	√
		Lotus corniculatus	Bird's-foot Trefoil	√	√	√		√				
		Phalaris arundinacea	Reed Canary Grass				√				√	√
		Phleum pratense	Timothy					√		√		
		Plantago major	Common Plantain					√				
		Poa palustris	Fowl Meadow Grass					√				
		Poa pratensis	Kentucky Blue Grass							√	√	√
		Poa spp.	Grass species	√	√							
		Scirpus atrovirens	Dark Green Bulrush			√						
		Solidago altissima	Tall Goldenrod	√						√		
		Solidago canadensis	Canada Goldenrod						√		√	√
		Symphyotrichum lanceolatum	Panicled Aster			√				√		
		Symphyotrichum novae-angliae	New England Aster							√		
		Symphyotrichum puniceum	Purple Stemmed Aster		√				√			
		Taraxacum officinale	Common Dandelion		√		√	√		√	√	√
		Tussilago farfara	Coltsfoot	√	√	√	√		√	√	√	√
		Typha angustifolia	Narrow-leaved Cattail					√				
		Waldsteinia fragarioides	Barren Strawberry		√							
			Moss species		√		√			√		
	4	*Bromus inermis ssp. inermis*	Smooth Brome						√			
		Calamagrostis canadensis	Canada Blue-joint								√	√
		Carex stipata	Awl-fruited Sedge						√			
		Carex vulpinoidea	Fox Sedge						√	√		
		Cirsium arvense	Canada Thistle	√	√						√	√
		Dactylis glomerata	Orchard Grass								√	√
		Echinochloa crusgalli	Barnyard Grass					√				
		Eleocharis smallii	Small's Spike-Rush		√							
		Epilobium hirsutum	Hairy Willow-Herb				√	√	√	√	√	√
		Equisetum arvense	Field Horsetail		√			√	√		√	√
		Equisetum pratense	Meadow Horsetail	√						√		
		Euthamia graminifolia	Grass-leaved Goldenrod			√	√	√	√	√		
		Festuca arundinacea	Tall Fescue								√	√
		Galium palustre	Marsh Bedstraw						√			
		Geum aleppicum	Yellow Avens								√	√
		Juncus tenuis	Path Rush				√		√		√	√
		Lactuca serriola	Prickly Lettuce	√								
		Lotus corniculatus	Bird's-foot Trefoil	√	√	√				√	√	√
		Medicago lupulina	Black Medick					√			√	√
		Mentha arvensis	Common Mint							√		
		Phalaris arundinacea	Reed Canary Grass				√					
		Plantago major	Common Plantain					√				
		Poa pratensis	Kentucky Blue Grass					√			√	√
		Poa spp.	Grass species	√	√	√			√			
		Scirpus atrovirens	Dark Green Bulrush						√			
		Solidago altissima	Tall Goldenrod	√								
		Solidago canadensis	Canada Goldenrod	√	√						√	√
		Symphyotrichum lanceolatum	Panicled Aster							√		
		Symphyotrichum novae-angliae	New England Aster							√		
		Symphyotrichum puniceum	Purple Stemmed Aster		√				√			
		Taraxacum officinale	Common Dandelion					√	√	√	√	√
		Trifolium hybridum	Alsike Clover	√				√				
		Tussilago farfara	Coltsfoot	√	√	√	√				√	√
		Typha angustifolia	Narrow-leaved Cattail					√				
		Typha latifolia	Common Cattail				√					
	5	*Bromus inermis ssp. inermis*	Smooth Brome						√			
		Calamagrostis canadensis	Canada Blue-joint								√	√
		Carex blanda	Smooth Sedge								√	√
		Carex flava	Yellow Sedge								√	√
		Carex spp.	Sedge species						√			
		Carex stricta	Stiff Sedge				√				√	√
		Carex trisperma var. trisperma	Three-seeded Sedge		√							
		Carex vulpinoidea	Fox Sedge				√		√		√	√
		Cerastium fontanum	Mouse-eared Chickweed								√	√
		Cirsium arvense	Canada Thistle	√		√						
		Dactylis glomerata	Orchard Grass							√	√	√
		Daucus carota	Queen Anne's Lace							√	√	√
		Echinochloa crusgalli	Barnyard Grass				√	√				
		Eleocharis smallii	Small's Spike-Rush					√				
		Epilobium hirsutum	Hairy Willow-Herb					√			√	√
		Epipactis helleborine	Helleborine							√		
		Equisetum arvense	Field Horsetail		√	√	√	√	√		√	√
		Equisetum pratense	Meadow Horsetail							√		
		Erigeron philadelphicus	Philadelphia Fleabane		√							
		Euthamia graminifolia	Grass-leaved Goldenrod				√	√	√	√	√	√
		Festuca arundinacea	Tall Fescue								√	√
		Juncus tenuis	Path Rush			√		√	√	√	√	√
		Lotus corniculatus	Bird's-foot Trefoil		√		√	√				
		Medicago lupulina	Black Medick						√		√	√
		Phalaris arundinacea	Reed Canary Grass				√					
		Phleum pratense	Timothy			√						
		Poa pratensis	Kentucky Blue Grass			√		√	√	√	√	√
		Poa spp.	Grass species	√	√				√			
		Scirpus atrovirens	Dark Green Bulrush					√	√			
		Solidago altissima	Tall Goldenrod	√					√	√	√	√
		Solidago canadensis	Canada Goldenrod	√	√	√			√		√	√
		Sonchus arvensis	Field Sow thistle					√				
		Symphyotrichum lanceolatum	Panicled Aster			√				√	√	√
		Symphyotrichum novae-angliae	New England Aster		√							
		Symphyotrichum puniceum	Purple Stemmed Aster		√							

Plot #	Sub plot #	Scientific Name	Common Name	2006	2007	2008	2009	2010	2011	2012	2013	2014
		Taraxacum officinale	Common Dandelion					√	√		√	√
		Tussilago farfara	Coltsfoot	√	√	√	√	√	√	√	√	√
			Moss species				√					
VEG-007	1	*Aralia nudicaulis*	Wild Sarsaparilla			√	√	√			√	√
		Arisaema triphyllum	Jack-in-the-pulpit				√					
		Carex laxiflora	Loose-flowered Sedge								√	√
		Carex spp.	Sedge species						√			
		Cicuta maculata	Spotted Water hemlock	√	√					√		
		Circaea quadrisulcata	Enchanter's Nightshade		√		√					
		Cystopteris bulbifera	Bulblet Fern				√		√			
		Dryopteris carthusiana	Spinulose Wood Fern		√							
		Geum var	Avens species								√	√
		Impatiens capensis	Spotted Jewelweed		√					√		
		Impatiens pallida	Pale Jewelweed						√			
		Lycopus americanus	American Water-horehound	√								
		Ranunculus hispidus var caricetorum	Swamp Buttercup	√								
		Scutellaria lateriflora	Mad-dog Skullcap	√								
		Taraxacum officinale	Common Dandelion		√							
		Thelypteris palustris	Marsh Fern	√								
		Veronica americana	American Brooklime							√		
	2	*Alisma subcordatum*	Small Water Plantain			√						
		Aralia nudicaulis	Wild Sarsaparilla				√					
		Arisaema triphyllum	Jack-in-the-pulpit								√	√
		Carex laxiflora	Loose-flowered Sedge								√	√
		Caltha palustris	Marsh Marigold	√								
		Cicuta maculata	Spotted Water hemlock	√	√		√	√		√	√	√
		Circaea alpina	Dwarf Enchanter's Nightshade				√					
		Circaea quadrisulcata	Enchanter's Nightshade	√	√				√			
		Cystopteris bulbifera	Bulblet Fern				√		√		√	√
		Dryopteris carthusiana	Spinulose Wood Fern	√				√				
		Fragaria vesca	Woodland Strawberry								√	√
		Hydrocotyle americana	Marsh-Water Pennywort	√			√	√				
		Hydrophyllum virginianum	Virginia Waterleaf			√						
		Impatiens capensis	Spotted Jewelweed	√	√	√	√	√		√	√	√
		Lycopus uniflorus	Northern Bugleweed			√	√					
		Lythraceae spp.	Loosestrife species			√						
		Maianthemum canadense	Canada Mayflower	√					√			
		Mitella nuda	Naked Miterwort								√	√
		Parthenocissus quinquefolia	Virginia Creeper	√								
		Poa spp.	Grass species		√							
		Polystichum acrostichoides	Christmas Fern	√								
		Prunella vulgaris ssp. lanceolata	Selfheal								√	√
		Ranunculus hispidus var caricetorum	Swamp Buttercup							√		
		Scutellaria galericulata	Common Skullcap						√			
		Scutellaria lateriflora	Mad-dog Skullcap					√				
		Stachys var	Hedge Nettle species							√		
		Taraxacum officinale	Common Dandelion						√			
		Thelypteris palustris	Marsh Fern	√								
		Trientalis borealis	Starflower	√					√			
		Veronica americana	American Brooklime							√		
		Veronica officinalis	Common Speedwell			√		√				
		Viola spp.	Violet Species						√			
			Moss species	√	√		√					
			Fern species						√			
	3	*Aralia nudicaulis*	Wild Sarsaparilla		√	√	√	√	√	√	√	√
		Arisaema triphyllum	Jack-in-the-pulpit			√	√	√				
		Carex blanda	Smooth Sedge							√		
		Carex gracillima	Graceful Sedge					√				
		Carex laxiflora	Loose-flowered Sedge				√					
		Clintonia borealis	Bluebead lily		√			√				
		Cystopteris bulbifera	Bulblet Fern		√					√	√	√
		Dryopteris carthusiana	Spinulose Wood Fern					√			√	√
		Dryopteris marginalis	Marginal Wood Fern				√					
		Impatiens capensis	Spotted Jewelweed	√							√	√
		Impatiens pallida	Pale Jewelweed						√			
		Maianthemum canadense	Canada Mayflower		√			√	√			
		Mitella nuda	Naked Miterwort								√	√
		Osmunda cinnamomea	Cinnamon Fern								√	√
		Poa spp.	Grass species		√							
		Scutellaria galericulata	Common Skullcap								√	√
		Taraxacum officinale	Common Dandelion						√			
		Trientalis borealis	Starflower						√		√	√
			Moss species	√	√		√			√		
	4	*Aralia nudicaulis*	Wild Sarsaparilla	√	√	√	√	√	√		√	√
		Arisaema triphyllum	Jack-in-the-pulpit	√		√						
		Carex laxiflora	Loose-flowered Sedge								√	√
		Carex spp.	Sedge species							√	√	√
		Cystopteris bulbifera	Bulblet Fern						√		√	√
		Dryopteris carthusiana	Spinulose Wood Fern	√	√							
		Epipactis helleborine	Helleborine				√	√		√		
		Fragaria virginiana	Wild Strawberry						√			
		Gymnocarpium dryopteris	Oak Fern				√			√		
		Impatiens capensis	Spotted Jewelweed								√	√
		Impatiens pallida	Pale Jewelweed						√			
		Maianthemum canadense	Wild Lily-of-the-Valley		√		√	√		√		
		Maianthemum stellatum	Star Flowered False Solomon's-seal			√						
		Poa spp.	Grass species		√		√		√			

Plot #	Sub plot #	Scientific Name	Common Name	2006	2007	2008	2009	2010	2011	2012	2013	2014
		Prunella vulgaris ssp. lanceolata	Selfheal						√			
		Taraxacum officinale	Common Dandelion					√				
		Thelypteris palustris	Marsh Fern	√								
		Trientalis borealis	Starflower						√		√	√
			Moss species	√	√							
	5	*Aralia nudicaulis*	Wild Sarsaparilla	√	√	√	√	√	√	√	√	√
		Arisaema triphyllum	Jack-in-the-pulpit		√							
		Carex spp.	Sedge species		√	√		√				
		Carex laxiflora	Loose-flowered Sedge								√	√
		Circaea quadrisulcata	Enchanter's Nightshade	√	√							
		Cystopteris bulbifera	Bulblet Fern				√		√		√	√
		Dryopteris carthusiana	Spinulose Wood Fern		√			√		√	√	√
		Dryopteris clintoniana	Clinton's Wood Fern		√							
		Epipactis helleborine	Helleborine				√	√				
		Fragaria virginiana	Wild Strawberry						√			
		Glyceria striata	Fowl Manna Grass							√		
		Impatiens pallida	Pale Jewelweed						√			
		Maianthemum canadense	Canada Mayflower	√	√	√	√	√	√	√	√	√
		Maianthemum racemosum	False Solomon's seal		√	√			√			
		Maianthemum stellatum	Star Flowered False Solomon's-seal			√	√	√				
		Taraxacum officinale	Common Dandelion	√						√		
		Thelypteris palustris	Marsh Fern	√								
		Tiarella cordifolia	Foam Flower					√				
		Trientalis borealis	Starflower		√						√	√
			Moss species	√	√	√	√			√		

Plot #	Sub plot #	Scientific Name	Common Name	2006	2007	2008	2009	2010	2011	2012	2013	2014
VEG-008	1	*Bidens frondosa*	Devil's beggarticks								√	√
		Caltha palustris	Marsh Marigold							√		
		Carex lacustris	Lake Sedge								√	√
		Carex stipata	Awl-fruited Sedge				√					
		Echinochloa crusgalli	Barnyard Grass				√					
		Eupatorium maculatum	Spotted Joe-Pye Weed				√					
		Galium palustre	Marsh Bedstraw				√	√				
		Geranium robertianum	Herb Robert	√								
		Glyceria striata	Fowl Manna Grass							√	√	√
		Impatiens capensis	Spotted Jewelweed	√			√	√		√		
		Lobelia siphilitica	Great Lobelia							√		
		Lysimachia nummularia	Moneywort		√							
		Lysimachia thrysiflora	Tufted Loosestrife		√							
		Mentha arvensis	Common Mint				√	√			√	√
		Mentha X piperita	Pepper Mint							√		
		Nasturtium officinale	Watercress							√	√	√
		Poa nemoralis	Wood Bluegrass				√					
		Poa palustris	Fowl Meadow Grass					√		√		
		Poa spp.	Grass species		√			√				
		Polygonum var									√	√
		Ranunculus acris	Tall Buttercup				√					
		Ranunculus repens	Creeping Buttercup					√		√		
		Symphyotrichum puniceum	Purple Stemmed Aster				√	√		√		
		Tussilago farfara	Coltsfoot							√	√	√
			Moss species		√							
	2	*Dryopteris carthusiana*	Spinulose Wood Fern			√						
		Geranium robertianum	Herb Robert		√	√						
		Solidago canadensis	Canada Goldenrod						√			
		Taraxacum officinale	Common Dandelion				√	√				
			Moss species	√	√	√	√					
	3	*Caltha palustris*	Marsh Marigold						√			
		Cystopteris bulbifera	Bulblet Fern				√				√	√
		Fragaria vesca	Woodland Strawberry			√						
		Lactuca serriola	Prickly Lettuce				√					
		Leersia oryzoides	Rice Cutgrass						√			
		Mentha X piperita	Pepper Mint							√		
		Nasturtium officinale	Watercress						√			
		Poa spp.	Grass species						√			
		Polygonum amphibium	Water Smartweed						√			
		Ranunculus flabellaris	Yellow Water-crowfoot						√			
		Scutellaria galericulata	Common Skullcap						√			
		Taraxacum officinale	Common Dandelion				√		√			
		Tussilago farfara	Coltsfoot				√			√	√	√
		Veronica anagallis-aquatica	Water Speedwell						√			
			Moss species	√	√		√					
	4	*Galium palustre*	Marsh Bedstraw						√			
		Geum laciniatum	Rough Avens						√			
		Poa spp.	Grass species		√				√			
		Ranunculus flabellaris	Yellow Water-crowfoot						√			
		Scirpus americanus	Common Three Square	√								
		Solidago canadensis	Canada Goldenrod						√			
		Taraxacum officinale	Common Dandelion	√	√							
		Tussilago farfara	Coltsfoot						√		√	√
			Moss species	√	√	√	√					
	5	*Caltha palustris*	Marsh Marigold	√		√			√			
		Carex aquatilis	Water Sedge				√					
		Carex lacustris	Lake Sedge			√						
		Galium palustre	Marsh Bedstraw				√					
		Impatiens capensis	Spotted Jewelweed	√	√					√		
		Leersia oryzoides	Rice Cutgrass				√					
		Lycopus uniflorus	Northern Bugleweed			√						
		Mentha arvensis	Common Mint	√	√		√	√				
		Mentha X piperita	Pepper Mint							√		
		Nasturtium officinale	Watercress					√	√	√	√	√
		Poa nemoralis	Wood Bluegrass				√					
		Poa spp.	Grass species		√			√				
		Ranunculus acris	Tall Buttercup				√					
		Ranunculus flabellaris	Yellow Water-crowfoot			√						
		Ranunculus repens	Creeping Buttercup					√		√	√	√
		Symphyotrichum lanceolatum var. lanc	Tall White Aster	√								
		Symphyotrichum puniceum	Purple Stemmed Aster				√					
		Taraxacum officinale	Common Dandelion	√				√				
		Tussilago farfara	Coltsfoot		√							
		Veronica anagallis-aquatica	Water Speedwell						√			
		Veronica officinalis	Common Speedwell			√						
		Waldsteinia fragarioides	Barren Strawberry		√							

Plot #	Sub plot #	Scientific Name	Common Name	2006	2007	2008	2009	2010	2011	2012	2013	2014
VEG-009	1	*Carex stipata*	Awl-fruited Sedge							√		
		Circaea quadrisulcata	Enchanter's Nightshade		√							
		Cirsium arvense	Canada Thistle							√		
		Equisetum arvense	Field Horsetail								√	√
		Equisetum palustre	Marsh Horsetail		√							
		Equisetum pratense	Meadow Horsetail							√		
		Eupatorium maculatum	Spotted Joe-Pye Weed								√	√
		Galium palustre	Marsh Bedstraw						√			
		Lysimachia ciliata	Fringed Loosestrife			√		√	√			
		Mentha arvensis	Common Mint		√				√	√		
		Phalaris arundinacea	Reed Canary Grass		√	√	√	√	√	√	√	√
		Scirpus atrovirens	Dark Green Bulrush							√		
		Symphyotrichum novae-angliae	New England Aster		√			√	√			
		Typha angustifolia	Narrow-leaved Cattail					√	√	√	√	√
	2	*Carex spp.*	Sedge species			√						
		Carex stipata	Awl-fruited Sedge				√					
		Circaea quadrisulcata	Enchanter's Nightshade		√							
		Equisetum arvense	Field Horsetail								√	√
		Equisetum pratense	Meadow Horsetail							√		
		Mentha arvensis	Common Mint					√	√			
		Phalaris arundinacea	Reed Canary Grass		√	√	√	√	√	√	√	√
		Typha angustifolia	Narrow-leaved Cattail					√	√	√	√	√
		Typha latifolia	Common Cattail		√		√					
	3	*Carex stipata*	Awl-fruited Sedge				√					
		Equisetum arvense	Field Horsetail								√	√
		Equisetum palustre	Marsh Horsetail		√							
		Euthamia graminifolia	Grass-leaved Goldenrod					√				
		Lysimachia ciliata	Fringed Loosestrife			√			√			
		Mentha arvensis	Common Mint				√					
		Phalaris arundinacea	Reed Canary Grass		√	√	√	√	√	√	√	√
		Ranunculus acris	Tall Buttercup					√	√			
		Solidago canadensis	Canada Goldenrod				√	√				
		Sonchus arvensis	Field Sow thistle			√						
		Symphyotrichum novae-angliae	New England Aster						√			
		Taraxacum officinale	Common Dandelion				√					
		Tussilago farfara	Coltsfoot				√					
		Typha angustifolia	Narrow-leaved Cattail						√	√	√	√
		Typha latifolia	Common Cattail		√							
	4	*Arabis glabra*	Tower-mustard			√						
		Carex spp.	Sedge species			√						
		Carex stipata	Awl-fruited Sedge		√		√	√				
		Circaea quadrisulcata	Enchanter's Nightshade		√							
		Eupatorium maculatum	Spotted Joe-Pye Weed								√	√
		Euthamia graminifolia	Grass-leaved Goldenrod			√		√	√	√		
		Lysimachia ciliata	Fringed Loosestrife			√	√	√		√	√	√
		Mentha arvensis	Common Mint				√	√	√			
		Phalaris arundinacea	Reed Canary Grass		√	√	√	√	√	√	√	√
		Poa palustris	Fowl Meadow Grass					√				
		Scutellaria lateriflora	Mad-dog Skullcap					√				
		Solidago canadensis	Canada Goldenrod						√			
		Symphyotrichum lanceolatum	Panicled Aster							√	√	√
		Symphyotrichum novae-angliae	New England Aster						√	√		
		Symphyotrichum puniceum	Purple Stemmed Aster		√							
		Tussilago farfara	Coltsfoot						√			
		Typha angustifolia	Narrow-leaved Cattail							√		
		Typha latifolia	Common Cattail		√		√	√			√	√
	5	*Equisetum arvense*	Field Horsetail			√						
		Equisetum var	Horsetail species						√			
		Galium palustre	Marsh Bedstraw					√				
		Lycopus uniflorus	Northern Bugleweed					√				
		Lysimachia ciliata	Fringed Loosestrife					√				
		Mentha arvensis	Common Mint					√	√		√	√
		Phalaris arundinacea	Reed Canary Grass		√	√	√	√	√	√	√	√
		Solidago canadensis	Canada Goldenrod								√	√
		Symphyotrichum puniceum	Purple Stemmed Aster								√	√
		Typha angustifolia	Narrow-leaved Cattail					√	√	√		
		Typha latifolia	Common Cattail				√				√	√

Plot #	Sub plot #	Scientific Name	Common Name	2006	2007	2008	2009	2010	2011	2012	2013	2014
VEG-016	1	*Boehmeria cylindrica*	False Nettle							√		
		Carex lupulina	Hop Sedge							√	√	√
		Carex spp.	Sedge species						√			
		Cicuta maculata	Spotted Water Hemlock							√		
		Heracleum lanatum	Cow Parsnip							√		
		Onoclea sensibilis	Sensitive Fern						√	√	√	√
		Phalaris arundinacea	Reed Canary Grass							√		
		Thelypteris palustris	Marsh Fern						√	√		
	2	*Boehmeria cylindrica*	False Nettle							√		
		Cicuta maculata	Spotted Water Hemlock							√		
		Phalaris arundinacea	Reed Canary Grass						√	√		
		Taraxacum officinale	Common Dandelion							√		
		Thelypteris palustris	Marsh Fern						√	√		
			Moss species						√			
	3	*Cicuta maculata*	Spotted Water Hemlock							√		
		Onoclea sensibilis	Sensitive Fern						√			
		Scutellaria galericulata	Common Skullcap						√			
		Thelypteris palustris	Marsh Fern							√		
	4	*Boehmeria cylindrica*	False Nettle							√		
		Cicuta maculata	Spotted Water Hemlock							√		
		Impatiens capensis	Spotted Jewelweed							√		
		Onoclea sensibilis	Sensitive Fern						√	√	√	
		Phalaris arundinacea	Reed Canary Grass						√	√	√	√
		Sium suave	Water Parsnip						√			
			Moss species						√			
	5	*Boehmeria cylindrica*	False Nettle							√		
		Carex lupulina	Hop sedge							√	√	√
		Carex spp.	Sedge species						√			
		Cicuta maculata	Spotted Water Hemlock							√		
		Onoclea sensibilis	Sensitive Fern							√		
		Phalaris arundinacea	Reed Canary Grass						√			
		Scutellaria galericulata	Common Skullcap						√			
		Thelypteris palustris	Marsh Fern						√	√	√	√
			Moss species						√			
VEG-018	1	*Aster spp.*	Aster species						√			
		Caltha palustris	Marsh Marigold						√	√	√	√
		Equisetum pratense	Meadow Horsetail						√	√		
		Glyceria striata	Fowl Manna Grass								√	√
		Lycopus uniflorus	Northern Bugleweed						√			
		Onoclea sensibilis	Sensitive Fern						√	√		
		Rhus radicans ssp. negundo	Poison Ivy						√			
		Taraxacum officinale	Common Dandelion								√	√
			Moss species						√			
	2	*Aster spp.*	Aster species						√			
		Caltha palustris	Marsh Marigold						√	√	√	√
		Daucus carota	Queen Anne's Lace								√	√
		Echinocystis lobata	Wild Cucumber								√	√
		Epilobium hirsutum	Hairy Willow-Herb						√			
		Equisetum arvense	Field Horsetail								√	√
		Equisetum pratense	Meadow Horsetail						√			
		Impatiens capensis	Spotted Jewelweed						√	√		
		Lycopus uniflorus	Northern Bugleweed						√			
		Mentha arvensis	Common Mint								√	√
		Onoclea sensibilis	Sensitive Fern						√	√		√
		Phalaris arundinacea	Reed Canary Grass						√			
		Solidago canadensis	Canada Goldenrod						√			
		Solidago gigantea	Late Goldenrod						√		√	√
		Symphyotrichum lanceolatum	Panicled Aster							√	√	√
		Rhus radicans ssp. negundo	Poison Ivy						√			
			Moss species						√			
	3	*Caltha palustris*	Marsh Marigold						√	√	√	√
		Equisetum arvense	Field Horsetail								√	√
		Equisetum pratense	Meadow Horsetail						√	√		
		Galium palustre	Marsh Bedstraw						√	√	√	√
		Glyceria striata	Fowl Manna Grass							√	√	√
		Impatiens capensis	Spotted Jewelweed						√	√		
		Mentha arvensis	Common Mint						√		√	√
		Onoclea sensibilis	Sensitive Fern						√	√	√	√
		Poa spp.	Grass species						√			
		Symphyotrichum lanceolatum	Panicled Aster								√	√
		Symphyotrichum puniceum	Purple Stemmed Aster								√	√
	4	*Caltha palustris*	Marsh Marigold						√	√	√	√
		Equisetum arvense	Field Horsetail								√	√
		Equisetum pratense	Meadow Horsetail						√	√		
		Impatiens capensis	Spotted Jewelweed						√	√		
		Galium palustre	Marsh Bedstraw								√	√
		Glyceria striata	Fowl Manna Grass							√	√	√
		Mentha arvensis	Common Mint						√			
		Onoclea sensibilis	Sensitive Fern						√	√	√	√
		Poa spp.	Grass species						√			
		Polygonatum pubescens	Hairy Solomon's Seal							√		
			Moss species						√			
	5	*Cicuta maculata*	Spotted Water Hemlock							√		
		Dryopteris carthusiana	Spinulose Wood Fern						√		√	√
		Dryopteris marginalis	Marginal Wood Fern						√			
		Epilobium hirsutum	Hairy Willow-Herb						√	√		
		Equisetum arvense	Field Horsetail								√	√

Plot #	Sub plot #	Scientific Name	Common Name	2006	2007	2008	2009	2010	2011	2012	2013	2014
		Equisetum pratense	Meadow Horsetail						√			
		Glyceria striata	Fowl Manna Grass							√		
		Impatiens capensis	Spotted Jewelweed								√	√
		Lycopus uniflorus	Northern Bugleweed						√	√	√	√
		Onoclea sensibilis	Sensitive Fern						√	√	√	√
		Polygonatum pubescens	Hairy Solomon's Seal						√	√	√	√
		Rhus radicans ssp. negundo	Poison Ivy						√			
		Solidago altissima	Tall Goldenrod							√		
		Solidago gigantea	Late Goldenrod								√	√
		Solidago patula	Rough-Leaved Goldenrod						√			
		Solidago rugosa	Rough-stemmed Goldenrod							√	√	√
		Symphyotrichum lanceolatum	Panicled Aster							√	√	√
		Symphyotrichum lateriflorum	Calico Aster						√			
		Symphyotrichum puniceum	Purple Stemmed Aster								√	√
		Taraxacum officinale	Common Dandelion								√	√
			Moss species						√			

APPENDIX IV

Shrub Species Observed by Plot 2014

Appendix IV. Shrub Species By Plot (2014)

						Data	
Plot #	*Scientific Name*	Common Name	CC	CW	Weed	Number	Cover (%)
1	*Solanum dulcamara*	Bittersweet Nightshade	*	0	-2	75	3
	Salix petiolaris	Slender Willow	3	-4	0	50	60
	Ribes americanum	Wild Black Currant	4	-3	0	3	0.1
	Cornus amomum	Silky Dogwood	5	-4	0	1	0.1
2	*Solanum dulcamara*	Bittersweet Nightshade	*	0	-2	20	5
	Sambucus canadensis	Common Elderberry	5	-2	0	1	0.1
	Rhamnus cathartica	Common Buckthorn	*	3	-3	10	0.1
	Rubus pubescens	Dwarf Raspberry	4	-4	0	5	0.1
	Rhamnus frangula	Glossy Buckthorn	*	-1	-3	40	20
	Vitis riparia	Riverbank Grape	0	-2	0	5	0.1
	Lonicera tatarica	Tartarian Honeysuckle	*	3	-3	5	0.1
	Viburnum trilobum	High-bush cranberry	5	-3	0	4	1
3	*Rhamnus cathartica*	Common Buckthorn	*	3	-3	2	0.5
	Rhamnus frangula	Glossy Buckthorn	*	-1	-3	20	5
4	*Solanum dulcamara*	Bittersweet Nightshade	*	0	-2	50	1
	Rubus pubescens	Dwarf Raspberry	4	-4	0	12	2
	Rhamnus frangula	Glossy Buckthorn	*	-1	-3	15	5
	Vitis riparia	Riverbank Grape	0	-2	0	1	0.5
	Cornus amomum	Silky Dogwood	5	-4	0	1	1
	Parthenocissus vitacea	Woodbine	3	3	0	5	1
6	Salix petiolaris	Slender Willow	3	-4	0	1	1
	Cornus stolonifera	Red-osier Dogwood	2	-3	0	4	2
	Salix eriocephala	Heart-leaved Willow	4	-3	0	2	1
7	Cornus alternifolia	Alternate-leaved Dogwood	6	5	0	2	1
	Rhamnus cathartica	Common Buckthorn	*	3	-3	2	0.5
	Rubus pubescens	Dwarf Raspberry	4	-4	0	5	0.5
	Rhamnus frangula	Glossy Buckthorn	*	-1	-3	15	1
	Parthenocissus vitacea	Woodbine	3	3	0	1	1
8	*Solanum dulcamara*	Bittersweet Nightshade	*	0	-2	7	1.5
	Cornus alternifolia	Alternate-leaved Dogwood	6	5	0	1	5
	Rhamnus cathartica	Common Buckthorn	*	3	-3	30	1.5
	Rhamnus frangula	Glossy Buckthorn	*	-1	-3	30	2
	Vitis riparia	Riverbank Grape	0	-2	0	1	0.5
	Prunus virginiana	Chokecherry	2	1	0	1	0.5
	Cornus amomum	Silky Dogwood	5	-4	0	1	2
	Viburnum opulus	Guelder-rose	*	0	-1	6	1
	Parthenocissus vitacea	Woodbine	3	3	0	1	1
9	*Rubus idaeus*	Red Raspberry	0	-2	0	6	0.1
	Rhamnus cathartica	Common Buckthorn	*	3	-3	1	0.1
	Cornus amomum	Silky Dogwood	5	-4	0	30	1
	Rubus occidentalis	black raspberry	2	5	0	1	0.1
16	*Solanum dulcamara*	Bittersweet Nightshade	*	0	-2	3	0.5
	Rhamnus cathartica	Common Buckthorn	*	3	-3	25	0.5
	Rhamnus frangula	Glossy Buckthorn	*	-1	-3	25	0.5
	Vitis riparia	Riverbank Grape	0	-2	0	1	2
	Parthenocissus vitacea	Woodbine	3	3	0	1	0.5
18	*Solanum dulcamara*	Bittersweet Nightshade	*	0	-2	3	3
	Rhamnus cathartica	Common Buckthorn	*	3	-3	100	10
	Rubus pubescens	Dwarf Raspberry	4	-4	0	20	20
	Rhamnus frangula	Glossy Buckthorn	*	-1	-3	2	0.5
	Vitis riparia	Riverbank Grape	0	-2	0	90	5
	Ilex verticillata	Winterberry	5	-4	0	1	5
	Toxicodendron radicans ssp. ne	Poison Ivy	5	-1	0	40	5
	Parthenocissus vitacea	Woodbine	3	3	0	40	3

APPENDIX V
Shrub Species Observed by Plot 2006 - 2014

Appendix V. Shrub Species by Plot 2006-2014

			Year								
Plot #	**Scientific Name**	**Common Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
1	*Ribes americanum*	Wild Black Currant									√
	Ribes triste	Swamp Red Currant						√	√		
	Rubus idaeus	Red Raspberry	√	√			√	√			
	Salix eriocephala	Heart-leaved Willow					√				
	Salix petiolaris	Slender Willow	√		√	√	√		√	√	√
	Sambucus canadensis	Common Elderberry	√								
	Solanum dulcamara	Bittersweet Nightshade	√	√	√	√	√	√	√	√	√
	Salix lucida	Shining Willow						√			
	Parthenocissus quinquefolia	Virginia Creeper	√	√							
	Cornus amomum	Silky Dogwood								√	√
2	*Cornus alternifolia*	Alternate-leaved Dogwood	√	√							
	Cornus stolonifera	Red-osier Dogwood					√				
	Lonicera tatarica	Tartarian Honeysuckle								√	√
	Rhamnus cathartica	Common Buckthorn	√	√	√	√		√	√	√	√
	Rhamnus frangula	Glossy Buckthorn	√				√	√	√	√	√
	Ribes americanum	Wild Black Currant	√	√			√	√			
	Rubus allegheniensis	Common Blackberry		√							
	Rubus idaeus	Red Raspberry	√								
	Rubus pubescens	Dwarf Raspberry	√	√		√	√	√		√	√
	Sambucus canadensis	Common Elderberry								√	√
	Solanum dulcamara	Bittersweet Nightshade	√	√	√	√	√	√	√	√	√
	Viburnum trilobum	High-bush cranberry									√
	Vitis riparia	Riverbank Grape						√	√	√	√
	Parthenocissus quinquefolia	Virginia Creeper	√	√			√				
	Parthenocissus vitacea	Woodbine								√	
3	*Cornus alternifolia*	Alternate-leaved Dogwood	√	√	√	√	√	√	√	√	
	Cornus stolonifera	Red-osier Dogwood					√				
	Rhamnus cathartica	Common Buckthorn	√	√	√	√	√	√	√	√	√
	Rhamnus frangula	Glossy Buckthorn	√				√	√	√	√	√
	Ribes triste	Swamp Red Currant					√				
	Solanum dulcamara	Bittersweet Nightshade							√		
	Viburnum trilobum	High-bush cranberry	√								
	Vitis riparia	Riverbank Grape	√	√							
	Parthenocissus quinquefolia	Virginia Creeper	√	√	√	√	√		√		
	Carpinus caroliniana	Blue Beech							√		
4	*Cornus stolonifera*	Red-osier Dogwood	√	√	√	√	√	√			
	Rhamnus cathartica	Common Buckthorn	√		√		√	√	√	√	
	Rhamnus frangula	Glossy Buckthorn	√			√	√	√	√	√	√
	Ribes americanum	Wild Black Currant							√		
	Rubus pubescens	Dwarf Raspberry	√	√		√			√	√	√
	Sambucus canadensis	Common Elderberry					√				
	Solanum dulcamara	Bittersweet Nightshade	√	√	√	√	√	√	√	√	√
	Vitis riparia	Riverbank Grape					√				√
	Ribes var	Currant species		√							
	Parthenocissus quinquefolia	Virginia Creeper	√	√		√	√	√	√		
	Cornus amomum	Silky Dogwood							√	√	√
	Parthenocissus vitacea	Woodbine								√	√
5	*Cornus alternifolia*	Alternate-leaved Dogwood		√							
	Rhamnus cathartica	Common Buckthorn		√		√		√			
6	*Cornus stolonifera*	Red-osier Dogwood	√	√	√	√		√	√	√	√
	Rhamnus cathartica	Common Buckthorn							√		
	Salix bebbiana	Bebb's Willow			√			√			
	Salix eriocephala	Heart-leaved Willow							√	√	√
	Salix petiolaris	Slender Willow							√	√	√
	Salix var	Willow species		√				√			
7	*Cornus alternifolia*	Alternate-leaved Dogwood	√	√	√		√		√	√	√
	Prunus virginiana	Chokecherry								√	
	Rhamnus cathartica	Common Buckthorn				√	√		√	√	√
	Rhamnus frangula	Glossy Buckthorn	√				√	√	√	√	√

	Ribes americanum	Wild Black Currant			√						
	Rubus pubescens	Dwarf Raspberry	√	√					√	√	√
	Solanum dulcamara	Bittersweet Nightshade	√	√		√	√	√	√	√	
	Viburnum trilobum	High-bush cranberry				√				√	
	Hamamelis virginiana	Witch Hazel			√		√				
	Parthenocissus quinquefolia	Virginia Creeper	√	√	√		√	√	√		
	Parthenocissus vitacea	Woodbine									√
	Amelanchier arborea	Downy Serviceberry								√	
8	*Cornus alternifolia*	Alternate-leaved Dogwood	√			√		√	√	√	√
	Cornus stolonifera	Red-osier Dogwood	√	√	√		√	√			
	Crataegus spp.	Hawthorn species	√								
	Echinocystis lobata	Wild Cucumber		√	√						
	Lonicera tatarica	Tartarian Honeysuckle	√	√	√	√	√	√	√	√	
	Prunus virginiana	Chokecherry			√	√				√	√
	Rhamnus cathartica	Common Buckthorn	√	√		√			√	√	√
	Rhamnus frangula	Glossy Buckthorn	√	√		√	√		√	√	√
	Ribes americanum	Wild Black Currant		√							
	Ribes triste	Swamp Red Currant	√								
	Rubus idaeus	Red Raspberry	√	√	√		√	√			
	Rubus parviflorus	Sparse-flowered Thimbleberry				√	√				
	Rubus pubescens	Dwarf Raspberry	√								
	Solanum dulcamara	Bittersweet Nightshade	√	√	√	√	√	√	√	√	√
	Viburnum trilobum	High-bush cranberry				√	√				
	Vitis riparia	Riverbank Grape	√	√	√	√	√	√	√		√
	Rubus occidentalis	Black Raspberry							√		
	Viburnum opulus	Guelder-rose							√	√	√
	Aronia melanocarpa	Black Chokeberry							√		
	Parthenocissus vitacea	Woodbine									√
9	*Cornus stolonifera*	Red-osier Dogwood		√	√	√	√	√	√		
	Rhamnus cathartica	Common Buckthorn					√	√			√
	Rhamnus frangula	Glossy Buckthorn			√						
	Rubus idaeus	Red Raspberry				√	√	√		√	√
	Solanum dulcamara	Bittersweet Nightshade				√		√		√	
	Cornus amomum	Silky Dogwood								√	√
	Rubus occidentalis	Black Raspberry									√
	Cornus foemina	Gray Dogwood								√	
16	*Echinocystis lobata*	Wild Cucumber						√			
	Rhamnus cathartica	Common Buckthorn						√	√	√	√
	Rhamnus frangula	Glossy Buckthorn						√	√	√	√
	Solanum dulcamara	Bittersweet Nightshade						√	√	√	√
	Vitis riparia	Riverbank Grape									√
	Parthenocissus quinquefolia	Virginia Creeper						√	√		
	Parthenocissus vitacea	Woodbine								√	√
18	*Rhamnus cathartica*	Common Buckthorn						√	√	√	√
	Rhamnus frangula	Glossy Buckthorn						√	√	√	√
	Rubus pubescens	Dwarf Raspberry						√	√	√	√
	Solanum dulcamara	Bittersweet Nightshade						√	√	√	√
	Vitis riparia	Riverbank Grape						√		√	√
	Ilex verticillata	Winterberry						√	√	√	√
	Parthenocissus quinquefolia	Virginia Creeper						√	√		
	Toxicodendron radicans ssp. ne	Poison Ivy							√		√
	Parthenocissus vitacea	Woodbine								√	√
	Toxicodendron rydbergii	Western Poison-ivy								√	
Total			**42**	**37**	**25**	**30**	**40**	**48**	**52**	**55**	**54**

APPENDIX VI

Tree Species Observed by Plot 2014

Appendix VI. Tree Species Observed by Plot 2014

Vegetation Plot 1	**Reed-canary Grass Graminoid Mineral Meadow Marsh**					**MAMM1-3**
Species	Condition			#/plot	Composition (%)	Avg. dbh (cm)
	Ag	Ma	De			
No trees >10cm dbh found in plot						

Vegetation Plot 2	**White Cedar - conifer Organic Coniferous Swamp**					**SWCO1-2**
Species	Condition			#/plot	Composition (%)	Avg. dbh (cm)
	Ag	Ma	De			
Black Ash	1		3	4	31	15.12
White Cedar	3		3	6	46	18.25
Yellow Birch	3			3	23	19.20
Total	**7**	**0**	**6**	**13**	**100**	**17.52**

Canopy Closure (%): 93
Dead/Snagged Trees: 3
Moisture Regime: 3
Dominant Species: White Cedar
Trees Missing: 0 (#6 on significant angle)

Vegetation Plot 3	**Fresh-Moist Sugar Maple Deciduous Forest**					**FODM6**
Species	Condition			#/plot	Composition (%)	Avg. dbh (cm)
	Ag	Ma	De			
Sugar Maple	3			3	75	27.73
White Ash			1	1	25	33.00
Total	**3**	**0**	**0**	**4**	**100**	**30.37**

Canopy Closure (%): 97
Dead/Snagged Trees: 0
Moisture Regime: 2
Dominant Species: Sugar Maple
Trees Missing: 0

Vegetation Plot 4	**White Cedar - Hardwood Mineral Mixed Swamp**					**SWMM1-1**
Species	Condition			#/plot	Composition (%)	Avg. dbh (cm)
	Ag	Ma	De			
White Cedar	15		4	19	90	14.75
Black Ash	1			1	5	17.50
Red Maple			1	1	5	14.60
Total	**16**	**0**	**5**	**21**	**100.00**	**15.62**

Canopy Closure (%): 97
Dead/Snagged Trees: 0
Moisture Regime: 5
Dominant Species: White Cedar
Trees Missing: 0

Vegetation Plot 5	Fresh-Moist Hemlock - Hardwood Mixed Forest					FOMM6
Species	Condition			#/plot	Composition (%)	Avg. dbh (cm)
	Ag	Ma	De			
Black Cherry	1			1	6	13.20
Balsam Fir	3			3	18	20.07
White Cedar	12			12	71	13.44
White Pine	1			1	6	24.00
Total	**17**	**0**	**0**	**17**	**100**	**17.68**

Canopy Closure (%): 91
Dead/Snagged Trees: 0
Moisture Regime: 3
Dominant Species: White Cedar
Trees Missing: 0

Vegetation Plot 6	Reed-canary Grass Graminoid Mineral Meadow Marsh					MAMM1-3
Species	Condition			#/plot	Composition (%)	Avg. dbh (cm)
	Ag	Ma	De			
No trees >10cm dbh found in plot						

Vegetation Plot 7	White Cedar - Hardwood Mineral Mixed Swamp					SWMM1-1
Species	Condition			#/plot	Composition (%)	Avg. dbh (cm)
	Ag	Ma	De			
White Cedar	5	3	2	10	71	26.08
Red Maple			1	1	7	24.60
Yellow Birch		1		1	7	26.10
Green Ash	1			1	7	28.90
Eastern Hemlock	1			1	7	13.00
Total	**7**	**4**	**3**	**14**	**100**	**23.74**

Canopy Closure (%): 95
Dead/Snagged Trees: 2
Moisture Regime: 4
Dominant Species: White Cedar
Trees Missing: 0

Vegetation Plot 8	White Cedar - Hardwood Mineral Mixed Swamp					SWMM1-1
Species	Condition			#/plot	Composition (%)	Avg. dbh (cm)
	Ag	Ma	De			
White Cedar	3		1	4	80	29.08
White Elm	1			1	20	14.10
Total	**4**	**0**	**1**	**5**	**100**	**21.59**

Canopy Closure (%): 37
Dead/Snagged Trees: 1
Moisture Regime: 5
Dominant Species: White Cedar
Trees Missing: 0

Vegetation Plot 9	Cattail Mineral Shallow Marsh					MASM1-1
Species	Condition			#/plot	Composition (%)	Avg. dbh (cm)
	Ag	Ma	De			
No trees >10cm dbh found in plot						

Vegetation Plot 16	Silver Maple Mineral Deciduous Swamp					SWDM3-2
Species	Condition			#/plot	Composition (%)	Avg. dbh (cm)
	Ag	Ma	De			
Silver Maple	4	1		5	100	29.16
Total	**4**	**1**	**0**	**5**	**100**	**29.16**

Canopy Closure (%): 94
Dead/Snagged Trees: 0
Moisture Regime: 4
Dominant Species: Silver Maple
Trees Missing: 0

Vegetation Plot 18	Silver Maple Organic Deciduous Swamp					SWDO2-2
Species	Condition			#/plot	Composition (%)	Avg. dbh (cm)
	Ag	Ma	De			
Silver Maple		2		2	67	67.40
Green Ash			1	1	33	13.80
Total	**0**	**2**	**1**	**3**	**100**	**40.60**

Canopy Closure (%): 94
Dead/Snagged Trees: 0
Moisture Regime: 4
Dominant Species: Silver Maple
Trees Missing: 0

APPENDIX VII

Tree Species Observed by Plot 2006 - 2014

Appendix VII. Hanlon Creek Business Park - Overstorey Trees

			2006		2007		2008		2009		2010		2011		2012		2013		2014	
Plot #	**Tag #**	**Species**	**DBH**	**Condition**	**DBH**	**Condition**	**DBH**	**Condition**	**DBH**	**Condition**	**DBH**	**Condition**	**DBH**	**Condition**	**DBH**	**Condition**	**DBH**	**Condition**	**DBH**	**Condition**
001	No Trees >10cm dbh																			
002	2-1	White Cedar	28	Ma	27.5	De	28.3	Ag	28.0	Ag	29	Ma	28.6	Ma	28.7	Ma	29.9	Ag	28.9	Ag
	2-2	White Cedar	10.5	De	10.6	Sn	10.1	De	9.6	De	10.2	Sn	10	De	9.9	De	9.9	De	10	De
	2-3	White Cedar	17.2	De	17.0	De	16.4	De	16.4	Ag	17.2	De	16.1	De	16.7	Ag	16.8	Ag	16.9	De
	2-4	Yellow Birch	20.5	Ag	21.2	De	21.4	Ag	21.1	Ag	22.5	Ag	36	Ma	22.3	Ag	22.6	Ag	23.3	Ag
	2-5	White Cedar	13.8	Ag	15.0	De	14.9	De	14.4	De	15	Ag	14.3	De	14.7	Ag	14.7	De	14.7	De
	2-6	White Spruce	n/a	Sn		Sn	15.6	Sn		Sn	15.7	Sn	15.3	Sn		Mi		Mi	15.7	Sn
	2-7	Black Ash	14	Ag	14.1	Ag	13.9	Ag	14.0	Ag	14.5	Ag	13.3	Ag	14.3	Ag	14.3	Ag	14.9	De
	2-8	White Cedar	16	De	16.0	De	17.7	De	17.4	Ag	18.7	Ma	17.6	De	17.5	Ag	17.4	Ag	18	Ag
	2-9	Black Ash	n/a	Sn		Sn	24.6	Sn	23.8	De	24.4	Sn	22.1	Sn	22.1	Sn	23.7	Sn	24.1	Sn
	2-10	Yellow Birch	10.7	Ag	10.6	Ag	12.1	Ag	12.8	Ag	13.5	Ag	20.1	Ag	13.9	Ag	13.6	Ag	14.2	Ag
	2-11	Black Ash	14	Ag	12.1	Ag	12.4	Ag	12.2	Ag	13.2	Ag	11.6	Ag	13.4	Ag	13.1	Ag	13.6	De
	2-12	Black Ash	10	Ag	10.1	Ag	10	Ag	10.1	Ag	10.5	Ag	9.4	Ag	10.7	Ag	10.7	Ag	11	Ag
	2-13	White Elm	45.2	Ma	45.6	Ma	48.1	Ma		Sn	49.3	Sn	45.8	Sn	45.8	Sn	48.2	Sn	47.9	Sn
	2-14	Black Ash	10.7	Ag	11.0	Ag	11.2	Ag	11.2	Ag	11.6	Ag	10.9	Ag	11.6	Ag	11.8	Ag	12	De
	2-15	White Cedar	20	De	20.4	De	21.1	De	21.1	De	22	Ma	19.4	De	20	Ag	20.9	Ag	21	Ag
	2-16	Yellow Birch	19	Ag	19.0	Ag	20.4	Ag	19.4	Ag	20.5	Ag	19	Ag	19.75	De	19.7	Ag	20.1	Ag
003	3-1	Sugar Maple	16	Ag	15.8	Ag	16.3	Ag	16.7	Ag	17.2	Ag	17	Ag	17.5	Ag	18.4	Ag	17.8	Ag
	3-2	Sugar Maple	17	Ag	16.8	Ag	17.8	Ag	17.8	Ag	18.2	Ag	17.8	Ag	18.9	Ag	19.0	Ag	19.0	Ag
	3-3	White Ash	32	Ma	32.3	Ma	31.2	Ag	21.1	Ag	32	Ma	32	Ma	31.7	Ag	32.6	Ag	33	De
	3-4	Sugar Maple	40	Ag	39.7	Ma	42.9	Ag	43.4	Ma	44	Ma	42.2	Ma	44.9	Ag	45.2	Ag	46.4	Ag
004	4-1	White Cedar	14	Ma	13.7	Ag	14.5	Ag	14.1	Ag	14	Ag	14	Ag	14.2	Ag	14.5	Ag	14.5	Ag
	4-2	White Cedar	10	Ma	10.4	Ma	10.5	Ag	10.2	Ag	10.5	Ag	10	Ag	10.9	Ag	10.9	Ag	11	Ag
	4-3	White Cedar	12.8	Ma	12.8	Ag	14.2	Ag	14.8	Ag	14.8	Ag	14	Ag	14.8	Ag	15	Ag	15.3	Ag
	4-4	White Cedar	14	Ma	13.9	Ag	15.6	Ag	14.4	Ag	14.4	Ag	14.2	Ag	14.6	Ag	15.1	Ag	15.3	Ag
	4-5	White Cedar	11.4	De	11.0	Ag	11.2	De	11.3	Ag	11.4	Ag	10.8	De	11.2	De	11.5	De	11.5	De
	4-6	White Cedar	12.2	De	12.1	Ag	13.8	De	12.6	Ag	12.5	De	12.2	De	12.5	De	12.5	De	12.7	De
	4-7	White Cedar	10.3	De	9.5	Ag	10.2	De	10.3	Ag	10.3	De	9.6	De	10.1	De	10.3	De	10.2	De
	4-8	White Cedar	12.4	De	11.8	Ag	13.8	De	12.4	Ag	12.4	De	12.1	De	12.2	De	12.4	De	12.6	De
	4-9	White Cedar	20.2	De	20.4	De	0	Sn		Mi	21	De	19.5	De	21.1	De	Out of plot, removed			
	4-10	White Cedar	13.4	Ag	13.7	Ag	14	Ag	15.7	Ag	14.7	Ag	N/A	Mi	14.9	Ag	15.3	Ag	14.4	Ag
	4-11	White Cedar	14	Ma	14.5	Ag	19	Ag	18.6	Ag	18.8	Ag	18.5	Ag	19.4	Ag	19.4	Ag	20	Ag
	4-12	White Cedar	10.8	Ag	10.7	Ag	10.5	Ag	11.1	Ag	10.8	Ag	10.7	Ag	11	Ag	11.2	Ag	11.8	Ag
	4-13	White Cedar	12	Ag	10.7	Ag	11.5	Ag			15	Ag	11.2	Ag	14.7	Ag	14.8	Ag	15.3	Ag
	4-13	Black Ash					10	Ag	11.1	Ag	11.2	Ag	11.2	Ag	11.9	Ag	12.9	Ag	17.5	Ag
	4-14	White Cedar	16	Ma	15.3	Ag	16	Ag	16.9	Ag	16.6	Ag	16.2	Ag	16.6	Ag	16.8	Ag	18.7	Ag
	4-15	White Cedar	17	Ma	16.4	Ma	16.5	Ag	17.2	Ag	17.6	Ag	18	Ag	17.8	Ag	18.1	Ag	35.5	Ag
	4-16	Red Maple	38	De	35.6	De	35.2	De	36.1	Ma	35.7	De	37.5	De	35.7	De	36.3	De	14.6	De
	4-17	White Cedar	11.9	Ma	11.5	Ag	13.1	Ag	14.3	Ag	13.8	Ag	12.2	Ag	13.7	Ag	14	Ag	14.6	Ag
	4-18	White Cedar	12	Ma	12.1	Ag	13	Ag	13	Ag	13.6	Ag	13.3	Ag	13.7	Ag	13.9	Ag	11.4	Ag
	4-19	White Cedar	10	Ma	8.6	Ag	11.1	Ag	11.1	Ag	11.3	Ag	11.4	Ag	11.5	Ag	11.5	Ag	10.2	Ag
	4-19	White Cedar													10.9	Ag	11.3	Ag	11.5	Ag
	4-20	White Cedar									10	Ag	9.5	Ag	10	Ag	10	Ag	13.8	Ag

			2006		2007		2008		2009		2010		2011		2012		2013		2014	
Plot #	Tag #	Species	DBH	Condition	DBH	Condition	DBH	Condition	DBH	Condition	DBH	Condition	DBH	Condition	DBH	Condition	DBH	Condition	DBH	Condition
	5-1	White Cedar					11.1	Ag	10.9	Ag	11.1	Ag	10.3	Ag	11.9	Ag	11.4	Ag	11.4	Ag
	5-2	White Cedar	12	De	13.0	Ag	13.1	Ag	13.8	Ag	14.2	Ag	13.7	Ag	14.5	Ag	14.9	Ag	14.7	Ag
	5-3	White Cedar	12.2	Ag	11.9	Ag	12.3	Ag	12.2	Ag	12.2	Ag	11.7	Ag	12.6	Ag	12.4	Ag	12.4	Ag
	5-4	Black Cherry	10	Ag	10.2	Ag	11.5	Ag	11.5	Ag	12.1	Ag	11.2	Ag	12.8	Ag	12.6	Ag	13.2	Ag
	5-5	White Cedar	10.4	De	10.9	Ag	11.2	Ag	11.2	Ag	11.4	Ag	11.8	Ag	11.6	Ag	11.5	Ag	11.3	Ag
	5-6	White Cedar	10.3	Ag	11.1	Ag	10.9	Ag	11.3	Ag	11.7	Ag	11.8	Ag	12.4	Ag	12.4	Ag	12.5	Ag
	5-7	White Cedar	11.2	Ag	11.4	Ag	12	Ag	12.4	Ag	12.6	Ag	13	Ag	13	Ag	13	Ag	13.1	Ag
	5-8	White Cedar	10	De	10.2	Ag	10.9	Ag	10.5	Ag	10.7	Ag	10.2	Ag	10.9	Ag	11.2	Ag	11	Ag
005	5-9	White Cedar	12	De	11.8	Ag	11.8	Ag	12	Ag	12.8	Ag	12.6	Ag	12.5	Ag	12.9	Ag	12.7	Ag
	5-10	Balsam Fir	26.7	Ma	27.5	Ma	27.8	Ag	28.7	Ma	29.7	Ag	28.6	Ag	31.7	Ag	31	Ag	31.6	Ag
	5-11	White Cedar	25.1	Ma	16.6	Ma	15.8	Ag	24.3	De	24.8	Ma	24.7	Ag	25.4	Ag	25.6	Ag	25.5	Ag
	5-12	White Pine	18.2	Ma	18.5	Ma	19.2	Ag	20	Ag	20.75	Ag	21.2	Ag	22.4	Ag	23.2	Ag	24	Ag
	5-13	Balsam Fir	12.1	Ag	12.2	Ag	12.4	Ag	13	Ag	13.5	Ag	13.6	Ag	14.3	Ag	14.5	Ag	15.8	Ag
	5-14	Balsam Fir	10	Ag	9.7	Ag	10.2	Ag	10.5	Ag	10.6	Ag	11	Ag	11.4	Ag	11.4	Ag	12.8	Ag
	5-15	White Cedar	10.3	De	10.2	Ag	10.5	Ag	10.9	Ag	10.8	Ag	10.5	Ag	10.9	Ag	10.7	Ag	10.6	Ag
	5-16	White Cedar	13	De	13.2	Ag	14	Ag	14.5	Ag	14.8	Ag	11.6	Ag	15.1	Ag	15.2	Ag	15.4	Ag
	5-17	White Cedar													11	Ag	10.9	Ag	10.7	Ag
006	No Trees >10cm dbh																			
	7-1	White Cedar	18.3	Ma	17.7	Ag	18.1	Ag	18.5	Ag	18.5	Ag	18.7	Ag	18.5	Ag	18.7	Ag	18.9	Ag
	7-2	White Cedar	10	Ag	9.2	Ag	10.1	Ag	10	Ag	10.1	De	10.6	De	10.2	De	10.1	De	10.2	De
	7-3	White Cedar	25.6	Ma	27.2	Ma	27	Ag	27.8	Ag	28	Ma	27.9	Ag	28.2	Ag	28.7	Ag	28.8	Ag
	7-4	White Cedar	18.1	Ag	18.6	Ma	19.1	Ag	19.1	Ag	19.4	Ma	18.4	Ag	19.7	Ag	19.5	Ag	20	Ag
	7-5	White Cedar	14.7	Ag	14.9	Ag	15.8	Ag	16	Ag	16	Ag	1.4	Ag	16	Ag	16.1	De	14.1	De
	7-6	White Cedar	12.5	Ag	22.3	Ma	23.7	Ag	23.5	Ma	23.7	Ma	22.8	Ag	23.8	Ag	24.2	Ag	24.4	Ag
	7-7	White Cedar	37	Ma	36.9	Ma	35.2	Ma	36	Ma	37	Ma	36.9	Ma	36.9	Ma	37.5	Ma	37.5	Ma
007	7-8	Eastern Hemlock	11.5	Ag	11.5	Ag	11.5	Ag	12	Ag	12.2	Ag	11.9	Ag	12.8	Ag	12.7	Ag	13	Ag
	7-9	Eastern Hemlock	12	De	11.3	De	11.6	Sn	11.7	De	11.7	Sn	11.7	Sn	11	Sn	11.6	Sn	11.9	Sn
	7-10	Eastern Hemlock					12.4	Ag	11.5	Ag	11.5	Ag	11.1	Ag	11.7	Ag	11.4	De	11.7	Sn
	7-11	Green Ash	26.3	Ma	25.3	Ma	26.1	Ag	27	De	26.8	De	27.8	Ag	26.8	Ag	27.4	Ag	28.9	Ag
	7-12	White Cedar	43.3	Ma	45.9	Ma	45.5	Ma	46.3	Ma	46	Ma	48.3	Ma	45.7	Ma	45.8	Ma	46	Ma
	7-13	Yellow Birch	25	Ma	24.9	Ma	25	Ag	26.7	Ma	25.5	Ma	24.7	Ma	26	Ma	25.7	Ma	26.1	Ma
	7-14	White Cedar					22	Ag	22.4	De	22.4	Ma	22.3	Ma	21.9	Ag	22.5	Ag	23.8	Ag
	7-15	White Cedar	36.1	Ma	35.2	Ma	35.6	Ma	36.5	Ma	36.8	Ma	35.6	Ag	36.4	Ma	36.5	Ma	37.1	Ma
	7-16	Red Maple	24.8	Ag	24.6	Ag	24	Ag	24.3	De	24.3	Ma	24.4	Ma	24.2	Ag	24.5	De	24.6	De
	8-1	White Cedar	21.4	Ma	20.0	Ma	20.7	Ma	20.7	Ma	20.5	Ma	20.3	Ag	20.5	Ag	20.5	Ag	21.4	Ag
	8-2	White Cedar	29.4	De	29.7	Ma	32.7	Ma	35	Ma	33.4	Ma	31.2	Ag	36.4	Ma	36.6	Ma	36.7	Ag
008	8-3	White Cedar	25.5	Ma	21.0	Ma	20	Ag	24.4	De		Mi		Mi	22.1	Ag	22.3	Ag	22.4	Ag
	8-4	White Elm	13.5	Ag	13.3	De		Sn		Sn		Sn		Sn		Sn		Sn		Sn
	8-5	White Elm	10.3	Ag	10.4	Ag	11.5	Ag	12	Ag	12.5	Ma	12.9	Ag	13.3	Ag	13.7	Ag	14.1	Ag
	8-6	White Cedar	35.1	Ma	35.5	Ma	32.8	Ag	34.8	Ma	35	Ma	37.5	Ag	35	Ma	35.5	Ma	35.8	Ma

			2006		2007		2008		2009		2010		2011		2012		2013		2014	
Plot #	**Tag #**	**Species**	**DBH**	**Condition**	**DBH**	**Condition**	**DBH**	**Condition**	**DBH**	**Condition**	**DBH**	**Condition**	**DBH**	**Condition**	**DBH**	**Condition**	**DBH**	**Condition**	**DBH**	**Condition**
009	No Trees >10cm dbh																			
016	16-1	Silver Maple											11.8	Ag	12.5	Ag	13.2	Ag	14.4	Ag
	16-2	Silver Maple											48.2	Ma	52	Ma	52.1	Ma	53.6	Ma
	16-3	Silver Maple											25.2	Ma	28.5	Ag	28.5	Ag	28.9	Ag
	16-4	Silver Maple											27.6	Ma	27.8	Ag	28.9	Ag	30.3	Ag
	16-5	Silver Maple											16.3	Ag	18	Ag	18	Ag	18.6	Ag
018	18-1	Silver Maple											46.5	Ma	50	Ma	50.5	Ma	50.2	Ma
	18-2	Silver Maple											75.4	Ma	82.5	Ma	82.5	Ma	84.6	Ma
	18-3	Green Ash											13.4	De	13.8	De	14	De	13.8	De

Physical Conditions:
Ag = Actively Growing
Ma = Mature
De = Declining
Sn = Snag
Mi = Missing

APPENDIX VIII

2014Bird Species Observed by Plot 2014

Appendix VIII. Bird Species Observed by Plot in 2006 - 2014

Breeding Bird Plot 001	**MAMM1-3**												
		Breeding Evidence											**Incidental Observations**
											2014		
Common Name	**Scientific Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	13-Jun	25-Jun	**2014**
Alder Flycatcher	*Empidonax alnorum*						PR	PO					Eastern Meadowlark (S)
American Goldfinch	*Spinus tristis*	PR	X	PO	PO		PO	PR	PO	PO	1	1	Eastern Kingbird (S)
American Robin	*Turdus migratorius*			PR	PR	PR	PR	PO	PR	PO		1	Savannah Sparrow (S)
Baltimore Oriole	*Icterus galbula*		PR			PO	PO	PR		PR	1	1	Eastern Wood-pewee (S)
Bank Swallow	*Riparia riparia*						PO						Eastern Phoebe (S)
Barn Swallow	*Hirundo rustica*	PO	PR				PR	PO	PO				Grasshopper Sparrow (S)
Black-billed Cuckoo	*Coccyzus erythropthalmus*									PR		2	Barn Swallow (X)
Black-capped Chickadee	*Poecile atricapillus*	PO			PO	PO				PR	1	1	
Bobolink	*Dolichonyx oryzivorus*		PO		PO	PO							
Brown-headed Cowbird	*Molothrus ater*			PR			PO	PR		PO		3	
Cedar Waxwing	*Bombycilla cedrorum*	PO	PO		PR	PR		PO	PR	PR	4	2	
Chipping Sparrow	*Spizella passerina*			PR					PO				
Common Grackle	*Quiscalus quiscula*					PO	PO						
Common Yellowthroat	*Geothylpis trichas*		PO	PR	PR	PR	PO	PR	CO	PR	1	1	
Downy Woodpecker	*Picoides pubescens*				PO				PO	PO		1	
Eastern Kingbird	*Tyrannus tyrannus*	PO			PR	PO	PO	PO					
Eastern Meadowlark	*Sturnella magna*		PO	PO		PO		PO	PO				
Eastern Wood-pewee	*Contopus virens*			PO			PO	PO					
European Starling	*Sturnus vulgaris*				X	X							
Flycatcher species		PO		X									
Grasshopper Sparrow	*Ammodramus savannarum*								PO				
Gray Catbird	*Dumetella carolinensis*				PO		PO		PO	PO		1	
Hairy Woodpecker	*Picoides villosus*								PR				
House Wren	*Troglodytes aedon*					PO			PO				
House Finch	*Carpodacus mexicanus*			CO									
Killdeer	*Charadrius vociferus*								PO				
Least Flycatcher	*Empidonax minimus*			PO									
Mallard	*Anas platyrhynchos*					X			PR	PO		2	
Mourning Dove	*Zenaida macroura*			PO				PO	PO	PO	1	1	
Northern Cardinal	*Cardinalis cardinalis*				PO				PO	PO		1	
Northern Flicker	*Colaptes auratus*	PR						PO	PO				
Northern Waterthrush	*Parkesia noveboracensis*									PO		1	
Passerine species		PO											
Red-eyed Vireo	*Vireo olivaceus*				X								
Red-winged Blackbird	*Agelaius phoeniceus*	PR	CO	PR	PR	PR	CO	PR	PR	PO	4	8	
Ring-billed Gull	*Larus delawarensis*						X						
Rock Pigeon	*Columba livia*					X				PO	2		
Rose-breasted Grosbeak	*Pheucticus ludovicianus*				PO								
Savannah Sparrow	*Passerculus sandwichensis*		PR		PO	PR		PR	PR				
Scarlet Tanager	*Piranga olivacea*	PO											
Song Sparrow	*Melospiza melodia*	PR	PR	PR	PR	PR	PR	PR	PR	PR	2	2	
Swamp Sparrow	*Melospiza georgiana*	PO	PO		PO			PR					
Tennessee Warbler	*Oreothlypis peregrina*	PO											
Tree Swallow	*Tachycineta bicolor*			PO	PO	PO							
Warbling Vireo	*Vireo gilvis*				PO	PR	PR	PR	PR				
Willow Flycatcher	*Empidonax traillii*				PR	PR			PR	PR	2	1	
Yellow Warbler	*Setophaga petechia*		X	PO	PR	PR	PO	PR	PR	PR	1	1	
Yellow-billed Cuckoo	*Coccyzus americanus*	PO											
Total	**43**	14	12	15	21	20	17	19	23	19	**20**	**31**	

Breeding Bird Plot 002	SWCO1-2												
		Breeding Evidence											Incidental Observations
											2014		
Common Name	**Scientific Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	13-Jun	25-Jun	**2014**
American Crow	*Corvus brachyrhynchos*		PO	PO		PO			PO				Killdeer (S)
American Goldfinch	*Spinus tristis*						PR						
American Robin	*Turdus migratorius*		PR	PR	PR	PO		PO	PO	PO		2	
Baltimore Oriole	*Icterus galbula*		PR		PO								
Bank Swallow	*Riparia riparia*						X						
Black-capped Chickadee	*Poecile atricapillus*		PO	PR	PO	PO	PO	PR	PR	PR	4	3	
Blue Jay	*Cyanocitta cristata*	PO			PR	PO		PR	PO	PO		2	
Brown-headed Cowbird	*Molothrus ater*						PO						
Cedar Waxwing	*Bombycilla cedrorum*	PO					PR	PO					
Chestnut-sided Warbler	*Setophaga pensylvanica*	PO											
Common Grackle	*Quiscalus quiscula*			PO				PO		PO		1	
Common Yellowthroat	*Geothylpis trichas*			PR	PO		PO		PR	PR	1	1	
Downy Woodpecker	*Picoides pubescens*	PO		PO					PO				
Eastern Kingbird	*Tyrannus tyrannus*								PO				
Eastern Meadowlark	*Sturnella magna*						PO						
Eastern Wood-pewee	*Contopus virens*	PO	PO		PO	PR		PO	PR	PR	1	1	
European Starling	*Sturnus vulgaris*								PO				
Great Crested Flycatcher	*Myiarchus crinitus*		PO		PO			PO		PR	1	1	
Hairy Woodpecker	*Picoides villosus*							PO					
House Wren	*Troglodytes aedon*		PO	PO	PO	PO		PR	PO	PR	1	1	
Indigo Bunting	*Passerina cyanea*	PO		PO									
Killdeer	*Charadrius vociferus*				PR			PO					
Mourning Dove	*Zenaida macroura*					PO		PR					
Northern Cardinal	*Cardinalis cardinalis*		PO		PO			PO	PR				
Northern Flicker	*Colaptes auratus*				PO								
Northern Waterthrush	*Parkesia noveboracensis*					PR		PR	PR	PR	1	1	
Passerine species		PO											
Red-bellied Woodpecker	*Melanerpes carolinus*								PO				
Red-breasted Nuthatch	*Sitta canadensis*							PO					
Red-winged Blackbird	*Agelaius phoeniceus*	PO			PO		PO	PO					
Rose-breasted Grosbeak	*Pheucticus ludovicianus*					PR				PR	1	1	
Song Sparrow	*Melospiza melodia*	PR	PR	PR	PR	PR	PR	PR	PR				
Turkey Vulture	*Cathartes aura*						X						
Wabler species		PO											
Warbling Vireo	*Vireo gilvis*						PO						
Yellow Warbler	*Setophaga petechia*						PO						
Total	**33**	10	9	9	13	10	12	16	14	10	**10**	**14**	

Breeding Bird Plot 003	**FODM6**												
		Breeding Evidence											**Incidental Observations**
											2014		
Common Name	**Scientific Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	13-Jun	25-Jun	**2014**
American Crow	*Corvus brachyrhynchos*	PR	PO		PR	PO	PO		PO				Song Sparrow (S)
American Goldfinch	*Spinus tristis*									PO		2	Eastern Wood-pewee (S)
American Robin	*Turdus migratorius*		PR	PR	PO	PO	PO	PO	PO	PR	1	1	Willow Flycatcher (S)
Baltimore Oriole	*Icterus galbula*		PO						PO				
Black-billed Cuckoo	*Coccyzus erythropthalmus*				PO								
Black-capped Chickadee	*Poecile atricapillus*	PR		PO		PO	PO	PO	PR	PO	1		
Blue Jay	*Cyanocitta cristata*			PR	PO	X		PO	PO	PO		3	
Brown-headed Cowbird	*Molothrus ater*					PO	PO						
Cedar Waxwing	*Bombycilla cedrorum*						PO	PO	PO				
Common Grackle	*Quiscalus quiscula*			PO				PO					
Common Yellowthroat	*Geothylpis trichas*				PO	PR	PR	PO	PO				
Downy Woodpecker	*Picoides pubescens*					CO		PO	PO				
Eastern Wood-pewee	*Contopus virens*	PO	PO	PR	PR	PR		PR		PO		1	
European Starling	*Sturnus vulgaris*			PO				PO					
Gray Catbird	*Dumetella carolinensis*			PO									
Great Crested Flycatcher	*Myiarchus crinitus*	PO			PO	PR	PO	PO	PO				
House Wren	*Troglodytes aedon*			PR	PR	PO		PO	PR				
Indigo Bunting	*Passerina cyanea*					PO		PR					
Northern Cardinal	*Cardinalis cardinalis*	PO			PR				PR				
Red-bellied Woodpecker	*Melanerpes carolinus*								PO				
Red-breasted Nuthatch	*Sitta canadensis*								PO				
Red-eyed Vireo	*Vireo olivaceus*	PR	PO		PO	PR		PO	PR	PR	1	1	
Red-tailed Hawk	*Buteo jamaicensis*		PR		PO								
Red-winged Blackbird	*Agelaius phoeniceus*			PO	PR	PO							
Ring-billed Gull	*Larus delawarensis*								PO				
Rose-breasted Grosbeak	*Pheucticus ludovicianus*				PO								
Song Sparrow	*Melospiza melodia*	PR	PO	PR	PO	PR	PR	PO	PR	PO		3	
Warbling Vireo	*Vireo gilvis*							PO					
White-breasted Nuthatch	*Sitta carolinensis*						PO						
Wood Thrush	*Hylocichla mustelina*		PR										
Yellow Warbler	*Setophaga petechia*			PO					PO				
Total	**31**	7	8	11	14	14	9	15	17	7	**3**	**11**	

Breeding Bird Plot 004	**SWMM1-1**												
		Breeding Evidence											**Incidental Observations**
											2014		
Common Name	**Scientific Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	13-Jun	25-Jun	**2014**
American Crow	*Corvus brachyrhynchos*	PO	PR	PO	PO	X	PO		PO				Grasshopper Sparrow (S)
American Goldfinch	*Spinus tristis*		PO	X	PO	PO		PO	PO	PO		1	Red-winged Blackbird (S)
American Robin	*Turdus migratorius*	PO	PO	PO	PO	PO	PR	PR	PR	PR	2	2	Black-capped Chickadee (S)
Black-capped Chickadee	*Poecile atricapillus*	PO	PO	PR	CO	PO		CO		PR	2	1	Eastern Meadowlark (S)
Blue-gray Gnatcatcher	*Polioptila caerulea*				PO								American Goldfinch (S)
Blue Jay	*Cyanocitta cristata*	PR	PR		PO	PO	PO	PO	PO	PR	1	2	American Robin (S)
Brown-headed Cowbird	*Molothrus ater*				PO	X			PO	PO	1		Canada Goose (H)
Cedar Waxwing	*Bombycilla cedrorum*			PO		PO				PO		2	Song Sparrow (S)
Chipping Sparrow	*Spizella passerina*		PO	PO					PR				Green Heron (X)
Common Grackle	*Quiscalus quiscula*	PO		X	CO		PO		PO				Bank Swallow (H)
Common Yellowthroat	*Geothylpis trichas*	CO	PO	PR	PR	PR		PR	PO	PO	1		
Downy Woodpecker	*Picoides pubescens*			PO									
European Starling	*Sturnus vulgaris*						PR		CO				
Gray Catbird	*Dumetella carolinensis*				PO			PO					
Hairy Woodpecker	*Picoides villosus*	PO											
House Wren	*Troglodytes aedon*								PO				
Mallard	*Anas platyrhynchos*		X										
Mourning Dove	*Zenaida macroura*								PO				
Northern Cardinal	*Cardinalis cardinalis*	PO		PO	PR	PO		PO	PO	PO		1	
Northern Flicker	*Colaptes auratus*					PO		PO					
Northern Waterthrush	*Parkesia noveboracensis*				PO	PO	PO						
Pine Warbler	*Setophaga pinus*					PO							
Red-eyed Vireo	*Vireo olivaceus*						PO						
Red-tailed Hawk	*Buteo jamaicensis*		PO										
Red-winged Blackbird	*Agelaius phoeniceus*	PR	PR	PO	PO	PO	PO		PO	PO		1	
Savannah Sparrow	*Passerculus sandwichensis*			PO				PO	PO				
Scarlet Tanager	*Piranga olivacea*							PO					
Song Sparrow	*Melospiza melodia*	PO	PO	PR	PO	PR	PO	PR	PR				
Swamp Sparrow	*Melospiza georgiana*	PO			PO			PR					
White-breasted Nuthatch	*Sitta carolinensis*						PO						
Wood Thrush	*Hylocichla mustelina*			PO									
Yellow-bellied Sapsucker	*Sphyrapicus varius*						PO						
Yellow Warbler	*Setophaga petechia*			PO		PO			PO	PR	1	1	
Total	**33**	11	11	15	15	15	11	12	16	10	**8**	**11**	

Breeding Bird Plot 005	**FOMM6**												
		Breeding Evidence											**Incidental Observations**
											2014		
Common Name	**Scientific Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	13-Jun	25-Jun	**2014**
American Crow	*Corvus brachyrhynchos*	PO		PO	PO	PO							Northern Cardinal (S)
American Goldfinch	*Spinus tristis*	PO	PO					PR	PO				Great Crested Flycatcher (S)
American Robin	*Turdus migratorius*	PO		PR	PO	PR	PR	PR	PR	PR	2	2	Song Sparrow (S)
Black-capped Chickadee	*Poecile atricapillus*	PR	PR	PO	PO	PR	PO	PR	PR	PO		2	
Blue Jay	*Cyanocitta cristata*	PR	PO	PO	PO	X	PO	PR	PR				
Brown Creeper	*Certhia americana*								PO				
Cedar Waxwing	*Bombycilla cedrorum*			PO									
Chipping Sparrow	*Spizella passerina*				PR								
Common Grackle	*Quiscalus quiscula*				CO								
Common Yellowthroat	*Geothylpis trichas*		PO		PO			PO					
Downy Woodpecker	*Picoides pubescens*			PO									
Gray Catbird	*Dumetella carolinensis*							PO					
Great Crested Flycatcher	*Myiarchus crinitus*	PO	PR	PO	PO	PO	PR	PO		PO		1	
Hairy Woodpecker	*Picoides villosus*								PO				
House Wren	*Troglodytes aedon*	PO											
Killdeer	*Charadrius vociferus*	PO					X		PO				
Mourning Dove	*Zenaida macroura*		PO						PO	PO	1		
Northern Cardinal	*Cardinalis cardinalis*	PO	PO		PO		PR	PR					
Northern Flicker	*Colaptes auratus*					PO			PO				
Pine Warbler	*Setophaga pinus*			PR				PO					
Red-breasted Nuthatch	*Sitta canadensis*				PO	X		PO					
Red-eyed Vireo	*Vireo olivaceus*				PR		PO	PO					
Red-winged Blackbird	*Agelaius phoeniceus*				PO								
Rose-breasted Grosbeak	*Pheucticus ludovicianus*						PR						
Song Sparrow	*Melospiza melodia*			PO		PO			PO				
Swamp Sparrow	*Melospiza georgiana*				PO								
White-breasted Nuthatch	*Sitta carolinensis*		PO		PO								
Total	**27**	9	8	9	14	8	8	11	10	4	**3**	**5**	

Breeding Bird Plot 006	**MAMM1-3**												
		Breeding Evidence											**Incidental Observations**
											2014		
Common Name	**Scientific Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	13-Jun	25-Jun	**2014**
American Crow	*Corvus brachyrhynchos*					PO			PO				Mourning Dove (S)
American Goldfinch	*Spinus tristis*	PR	PR	PR	PO	PO	PO	PR	PR	PR	1	4	Indigo Bunting (S)
American Redstart	*Setophaga ruticilla*					PO							
American Robin	*Turdus migratorius*	PR	PO	PO	PR	CO	PO	PR	PR	PR	3	2	
Baltimore Oriole	*Icterus galbula*			PO			PR						
Barn Swallow	*Hirundo rustica*	PO	PR	PR									
Black-capped Chickadee	*Poecile atricapillus*			PO	PO	PO				PO		2	
Blue Jay	*Cyanocitta cristata*	PO	PO					PO					
Brown-headed Cowbird	*Molothrus ater*				X	PO	PO		PR				
Cedar Waxwing	*Bombycilla cedrorum*				X	X		PO					
Common Grackle	*Quiscalus quiscula*			PO	X		PO						
Common Yellowthroat	*Geothylpis trichas*		PO	PR	PO	PO	PO	PR	PR	PR	2	2	
Eastern Meadowlark	*Sturnella magna*								PO				
Eastern Wood-pewee	*Contopus virens*			PO				PO					
European Starling	*Sturnus vulgaris*			X	PO			PO					
Field Sparrow	*Spizella pusilla*		PO				PO						
Gray Catbird	*Dumetella carolinensis*			PO			PO		PO				
Great Crested Flycatcher	*Myiarchus crinitus*		PO						PO				
Hairy Woodpecker	*Picoides villosus*							PO					
House Wren	*Troglodytes aedon*						PO						
Indigo Bunting	*Passerina cyanea*				PO					PO		2	
Killdeer	*Charadrius vociferus*								PO	PO		3	
Mallard	*Anas platyrhynchos*	PO	PR										
Mourning Dove	*Zenaida macroura*								PO				
Northern Cardinal	*Cardinalis cardinalis*	PO	PR		PO								
Northern Flicker	*Colaptes auratus*		CO			PO							
Northern Rough-winged Swal	*Stelgidopteryx serripennis*				PR			PO					
Northern Waterthrush	*Parkesia noveboracensis*					PO							
Red-tailed Hawk	*Buteo jamaicensis*						PR		PO				
Red-winged Blackbird	*Agelaius phoeniceus*	PR	CO	CO	CO	PR	PR	CO	PR	PR	4	2	
Ring-billed Gull	*Larus delawarensis*		X										
Rock Pigeon	*Columba livia*					X							
Savannah Sparrow	*Passerculus sandwichensis*				PO			PO	PO				
Song Sparrow	*Melospiza melodia*	PR	PR	PR	PR	PR	PR	PR	PR	PR	2	2	
Spotted Sandpiper	*Actitis macularia*							PO					
Tree Swallow	*Tachycineta bicolor*			PO		PO		PO					
Warbling Vireo	*Vireo gilvis*					PR	PR	PR	PO				
Willow Flycatcher	*Empidonax traillii*								PO				
Vesper Sparrow	*Pooecetes gramineus*				PO								
Yellow Warbler	*Setophaga petechia*				PR	PO	PR		PR	PO	2		
Total	**40**	8	13	13	16	16	14	15	17	9	**14**	**19**	

Breeding Bird Plot 007	SWMM1-1												
		Breeding Evidence											Incidental Observations
											2014		
Common Name	**Scientific Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	13-Jun	25-Jun	**2014**
American Crow	*Corvus brachyrhynchos*	PR	PO										Song Sparrow (S)
American Goldfinch	*Spinus tristis*	PO	PO	PR	PO	PO		PR					American Robin (S)
American Robin	*Turdus migratorius*	PR		PO	PO	PR	PR	PR	PR	PR	1	2	Solitary Sandpiper (P)
Baltimore Oriole	*Icterus galbula*				CO					PO	1		Red-tailed Hawk (S)
Bank Swallow	*Riparia riparia*									PO		1	
Black-capped Chickadee	*Poecile atricapillus*		PR	PO	PR	PO	PO	PO	PR				
Blue Jay	*Cyanocitta cristata*	PR	PO		PR	PO	PO	PO	PO	PO		1	
Brown Creeper	*Certhia americana*					PO	PO	PO	PO				
Canada Goose	*Branta canadensis*		X										
Cedar Waxwing	*Bombycilla cedrorum*			PO		PO		PO	PO				
Chipping Sparrow	*Spizella passerina*			PO	PO								
Common Grackle	*Quiscalus quiscula*				X		PO						
Downy Woodpecker	*Picoides pubescens*		X	PO									
Eastern Kingbird	*Tyrannus tyrannus*		PO										
Eastern Meadowlark	*Sturnella magna*			PO									
Eastern Wood-pewee	*Contopus virens*				PO	PO							
Field Sparrow	*Spizella pusilla*			PO	PO								
Gray Catbird	*Dumetella carolinensis*				PO								
Great Crested Flycatcher	*Myiarchus crinitus*		PR		PO	PO	PO	PO		PO	1		
Hairy Woodpecker	*Picoides villosus*	PO							PO				
Indigo Bunting	*Passerina cyanea*	PO			PO								
Killdeer	*Charadrius vociferus*						PO	PO	PO				
Northern Cardinal	*Cardinalis cardinalis*		PO	PO	PO		PO		PO	PR	1	1	
Northern Flicker	*Colaptes auratus*								PO				
Mourning Dove	*Zenaida macroura*								PO	PO	1		
Passerine Species		PO		PO		PO							
Red-breasted Nuthatch	*Sitta canadensis*					PR			PO				
Red-eyed Vireo	*Vireo olivaceus*				PO		PO			PR	1	1	
Savannah Sparrow	*Passerculus sandwichensis*							PO					
Song Sparrow	*Melospiza melodia*	PR	PO	PR	PR	PR	PR	PR	PR	PO		3	
Spotted Sandpiper	*Actitis macularia*							PO					
White-breasted Nuthatch	*Sitta carolinensis*		PO		PR		PR						
Total	**30**	8	11	11	16	11	11	11	12	9	**6**	**9**	

Breeding Bird Plot 008	SWMM1-1												
		Breeding Evidence											Incidental Observations
											2014		
Common Name	**Scientific Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	13-Jun	25-Jun	**2014**
American Crow	*Corvus brachyrhynchos*		PR		PO		PO			PO	1		Common Yellowthroat (S)
American Goldfinch	*Spinus tristis*	PR	PO	PR	PR	PO	PO	PR	PR	PO	2		Eastern Kingbird (S)
American Robin	*Turdus migratorius*	PO	PO	PR	PO	PO	PO	PR	PR	PR	2	2	Chipping Sparrow (S)
American Woodcock	*Scolopax minor*							PO					Savannah Sparrow (S)
Barn Swallow	*Hirundo rustica*								X				Grasshopper Sparrow (S)
Belted Kingfisher	*Megaceryle alcyon*					PO			PO	CO		1	Song Sparrow (S)
Black-billed Cuckoo	*Coccyzus erythropthalmus*				PO								American Crow (H)
Black-capped Chickadee	*Poecile atricapillus*		PR	PR	PR	PO	PO		PR	PO		1	
Blue Jay	*Cyanocitta cristata*	PO	PO		PR	PO	PO	PO		PO		1	
Brown-headed Cowbird	*Molothrus ater*		PO		PO	PO	PO		PO	PR	1	2	
Cedar Waxwing	*Bombycilla cedrorum*	PO			PO			PO					
Chipping Sparrow	*Spizella passerina*	PO											
Common Grackle	*Quiscalus quiscula*		PR	X	X		PO			PO	1		
Common Yellowthroat	*Geothylpis trichas*	PO		PO	PO	PO	PO	PO	PO	PO	1		
Eastern Kingbird	*Tyrannus tyrannus*									PO	1		
Eastern Meadowlark	*Sturnella magna*			PR	PO								
Eastern Wood-pewee	*Contopus virens*						PO						
Gray Catbird	*Dumetella carolinensis*	CO	PR		PR		CO	PO					
Great Crested Flycatcher	*Myiarchus crinitus*							PO					
Hairy Woodpecker	*Picoides villosus*	PO		PO									
House Wren	*Troglodytes aedon*						PO	PO					
Killdeer	*Charadrius vociferus*						PO		PO				
Mallard	*Anas platyrhynchos*		X			X	X		X				
Mourning Dove	*Zenaida macroura*						PO		PO	PO		1	
Northern Cardinal	*Cardinalis cardinalis*	PO		PO	PR		PO	PR	PO	PO		2	
Northern Flicker	*Colaptes auratus*						PO		PO				
Northern Waterthrush	*Parkesia noveboracensis*							PO					
Red-eyed Vireo	*Vireo olivaceus*						PO	PO					
Red-winged Blackbird	*Agelaius phoeniceus*	PO	PR	PR	PO		PO	PO	PR				
Ring-billed Gull	*Larus delawarensis*								X				
Savannah Sparrow	*Passerculus sandwichensis*			PO	PO			PR					
Song Sparrow	*Melospiza melodia*	PR	PR	PR	PR	PR	PR	PR	PR	PR	2	2	
Yellow Warbler	*Setophaga petechia*			PR	PO		PO		PR				
Total	**33**	11	11	12	17	9	20	15	16	13	**11**	**12**	

Breeding Bird Plot 009	**MASM1-1**												
		Breeding Evidence											**Incidental Observations**
											2014		
Common Name	**Scientific Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	13-Jun	25-Jun	**2014**
American Crow	*Corvus brachyrhynchos*			PO	PO	CO			PO				Savannah Sparrow (S)
American Goldfinch	*Spinus tristis*				PR	PO	PO		PR				Eastern Meadowlark (S)
American Robin	*Turdus migratorius*			PO	PR	PO	PR	PO	PO	PR	1	3	Tree Swallow (X)
Baltimore Oriole	*Icterus galbula*				PR		PO						
Barn Swallow	*Hirundo rustica*			PR	PO	PO		PO		X	1	1	
Black-capped Chickadee	*Poecile atricapillus*			PO									
Blue Jay	*Cyanocitta cristata*								X				
Bobolink	*Dolichonyx oryzivorus*				PO				PR				
Canada Goose	*Branta canadensis*		CO										
Cedar Waxwing	*Bombycilla cedrorum*									PO	2		
Chipping Sparrow	*Spizella passerina*						PO						
Common Grackle	*Quiscalus quiscula*				X		PO	PO					
Common Yellowthroat	*Geothylpis trichas*		PR	PO	PO	PR	PR	PO	PO	PR	1	2	
Eastern Kingbird	*Tyrannus tyrannus*				PR			PO					
Eastern Meadowlark	*Sturnella magna*				PR		PO	PR	PO				
Eastern Wood-pewee	*Contopus virens*				PO								
European Starling	*Sturnus vulgaris*				PO		PO	PO					
House Wren	*Troglodytes aedon*						PO						
Killdeer	*Charadrius vociferus*		PR		PR			PO	PO				
Mallard	*Anas platyrhynchos*		X			X	PO						
Northern Cardinal	*Cardinalis cardinalis*			PO									
Northern Flicker	*Colaptes auratus*						PO						
Red-tailed Hawk	*Buteo jamaicensis*			PO	PO								
Red-winged Blackbird	*Agelaius phoeniceus*		CO	CO	CO	PR	PR	PR	PR	PR	4	6	
Ring-billed Gull	*Larus delawarensis*		X	X									
Rock Pigeon	*Columba livia*							PO					
Savannah Sparrow	*Passerculus sandwichensis*		PR	PO	PO	PR	PO	PR	PR	PO		3	
Song Sparrow	*Melospiza melodia*			PO	PR	PR		PO	PR	PO		1	
Tree Swallow	*Tachycineta bicolor*		CO	PO				PO	PO				
Turkey Vulture	*Cathartes aura*							PO					
Warbling Vireo	*Vireo gilvis*								PO				
Wild Turkey	*Meleagris gallopavo*								PO				
Willow Flycatcher	*Empidonax traillii*				PO			PR	PO	PR	2	1	
Yellow Warbler	*Setophaga petechia*			PO	PO			PO					
Total	**34**		8	13	19	9	13	16	15	8	**11**	**17**	

Breeding Bird Plot 011	FODR1-1												
		Breeding Evidence											Incidental Observations
											2014		
Common Name	Scientific Name	2006	2007	2008	2009	2010	2011	2012	2013	2014	13-Jun	25-Jun	2014
American Crow	*Corvus brachyrhynchos*				PO	PO							Yellow Warbler (S)
American Goldfinch	*Spinus tristis*				X	PO	PO	PR	PR	PR	2	1	Northern Cardinal (S)
American Redstart	*Setophaga ruticilla*				PO			PO		PR	2	1	Mallard (H)
American Robin	*Turdus migratorius*				PO	PR	PR	PR	PR	PO		1	
Baltimore Oriole	*Icterus galbula*					PO	PO		PR				
Barn Swallow	*Hirundo rustica*					PO			X				
Black-capped Chickadee	*Poecile atricapillus*					PO	PO	PO	PR	PO	1		
Blue Jay	*Cyanocitta cristata*				PO				PO				
Brown-headed Cowbird	*Molothrus ater*									PO		1	
Cedar Waxwing	*Bombycilla cedrorum*					PO			PO	PO		1	
Chestnut-sided Warbler	*Setophaga pensylvanica*						PO						
Chipping Sparrow	*Spizella passerina*						PO			PO		1	
Cliff Swallow	*Petrochelidon pyrrhonota*								X				
Common Grackle	*Quiscalus quiscula*				X			PO	PO				
Downy Woodpecker	*Picoides pubescens*						PO						
Eastern Kingbird	*Tyrannus tyrannus*					PR							
Eastern Meadowlark	*Sturnella magna*				PO				PO				
Eastern Wood-pewee	*Contopus virens*				PO	PO			PO				
European Starling	*Sturnus vulgaris*							PO	CO	PO	1	5	
Gray Catbird	*Dumetella carolinensis*				PO	PO	PO	CO	PO	PO		3	
Horned Lark	*Eremophila alpestris*								PO				
House Wren	*Troglodytes aedon*				PR	PO							
Killdeer	*Charadrius vociferus*				PO					PO		1	
Mourning Dove	*Zenaida macroura*					PO	PR		PO				
Northern Cardinal	*Cardinalis cardinalis*				PO			PO		PO		1	
Northern Flicker	*Colaptes auratus*				PO				PO	PO		1	
Red-eyed Vireo	*Vireo olivaceus*						PO	PO	PO	PO		3	
Red-winged Blackbird	*Agelaius phoeniceus*				PO	PO	PO	PO	PR				
Rose-breasted Grosbeak	*Pheucticus ludovicianus*				PO					PO	1		
Savannah Sparrow	*Passerculus sandwichensis*					PR			PO				
Song Sparrow	*Melospiza melodia*				PR	PO	PO		PR	PR	1	2	
Tree Swallow	*Tachycineta bicolor*						PR						
Turkey Vulture	*Cathartes aura*								X				
Warbling Vireo	*Vireo gilvis*				PO	PO	PO	PO		PO		1	
White-breasted Nuthatch	*Sitta carolinensis*							PO					
Yellow Warbler	*Setophaga petechia*						PO	PR	PR	PO		1	
Total	**35**				17	16	15	13	22	17	**8**	**24**	

Breeding Bird Plot 016	SWDM3-2												
		Breeding Evidence											Incidental Observations
											2014		
Common Name	**Scientific Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	13-Jun	25-Jun	**2014**
American Crow	*Corvus brachyrhynchos*						PO		PO				Song Sparrow (S)
American Goldfinch	*Spinus tristis*						PO	PO		PR	1	1	European Starling (S)
American Redstart	*Setophaga ruticilla*						PO						Killdeer (S)
American Robin	*Turdus migratorius*						PR	CO	PR	PO	1	1	Savannah Sparrow (S)
Baltimore Oriole	*Icterus galbula*						PO		PO				Mallard (P)
Black-capped Chickadee	*Poecile atricapillus*						PO	PR					Mourning Dove (H)
Blue Jay	*Cyanocitta cristata*						PR						Belted Kingfisher (X)
Brown-headed Cowbird	*Molothrus ater*						PO		PO				Northern Cardinal (S)
Cedar Waxwing	*Bombycilla cedrorum*						PO						European Starling (S)
Downy Woodpecker	*Picoides pubescens*							PO					
Eastern Wood-pewee	*Contopus virens*							PO					
Hairy Woodpecker	*Picoides villosus*						PO						
Horned Lark	*Eremophila alpestris*								PO				
Killdeer	*Charadrius vociferus*						PO	PR	PO				
Red-eyed Vireo	*Vireo olivaceus*						PO		PO	PO	1		
Rose-breasted Grosbeak	*Pheucticus ludovicianus*									PO		1	
Savannah Sparrow	*Passerculus sandwichensis*						PO		PO				
Song Sparrow	*Melospiza melodia*						PR	PR	PR	PO		2	
Tree Swallow	*Tachycineta bicolor*						PO						
Warbling Vireo	*Vireo gilvis*						PR		PR				
Yellow-bellied Sapsucker	*Sphyrapicus varius*						PO						
Yellow Warbler	*Setophaga petechia*								PR				
Total	**21**						17	7	10	5	**3**	**5**	

Breeding Bird Plot 019	MEM													
		Breeding Evidence												Incidental Observations
											2014			
Common Name	**Scientific Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	13-Jun	25-Jun		**2014**
American Crow	*Corvus brachyrhynchos*							PR	PO					Easter Wood-pewee (S)
American Goldfinch	*Spinus tristis*						PO	PO	PR	PO		2		Blue Jay (S)
American Robin	*Turdus migratorius*						PO	PO	PR	PO	3			Northern Cardinal (S)
American Woodcock	*Scolopax minor*								PO					
Baltimore Oriole	*Icterus galbula*								PR					
Bank Swallow	*Riparia riparia*						PO							
Barn Swallow	*Hirundo rustica*						PO	PO	PO	X	2			
Blue Jay	*Cyanocitta cristata*							PO	PO	PO	1			
Bobolink	*Dolichonyx oryzivorus*							PR						
Brown-headed Cowbird	*Molothrus ater*						PO							
Cedar Waxwing	*Bombycilla cedrorum*							PO		PO		2		
Common Grackle	*Quiscalus quiscula*						PO	X	PO	PO	1	1		
Common Yellowthroat	*Geothylpis trichas*						PR	PO	PR	PO		2		
Eastern Kingbird	*Tyrannus tyrannus*									PO		1		
Eastern Meadowlark	*Sturnella magna*							PR						
Eastern Wood-pewee	*Contopus virens*						PO		PR	PO		1		
European Starling	*Sturnus vulgaris*								PO					
Gray Catbird	*Dumetella carolinensis*									PO		1		
Great Crested Flycatcher	*Myiarchus crinitus*								PO	PO		1		
House Wren	*Troglodytes aedon*								PO					
Indigo Bunting	*Passerina cyanea*							PO		PR	1	3		
Northern Cardinal	*Cardinalis cardinalis*								PR					
Northern Flicker	*Colaptes auratus*								PO					
Northern Rough-winged Swal	*Stelgidopteryx serripennis*								PO					
Red-bellied Woodpecker	*Melanerpes carolinus*								PO					
Red-winged Blackbird	*Agelaius phoeniceus*						PO	PR	PR	PO	2			
Savannah Sparrow	*Passerculus sandwichensis*							PO						
Song Sparrow	*Melospiza melodia*						PR	PR	CO	PR	3	2		
Tree Swallow	*Tachycineta bicolor*							PO	PO					
Warbling Vireo	*Vireo gilvis*								PO					
Willow Flycatcher	*Empidonax traillii*									PO	3			
Wood Thrush	*Hylocichla mustelina*								PO					
Yellow Warbler	*Setophaga petechia*							PO						
Total	**27**						10	16	22	15	**16**	**16**		

Breeding Bird Plot 020	Agricultural Field												
		Breeding Evidence											Incidental Observations
											2014		
Common Name	**Scientific Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	13-Jun	25-Jun	**2014**
American Crow	*Corvus brachyrhynchos*								PO	PO		2	Turkey Vulture (X)
American Goldfinch	*Spinus tristis*						PR	PR	PR				Warbling Vireo (S)
American Robin	*Turdus migratorius*						PO	PO	PR	PO		1	
Baltimore Oriole	*Icterus galbula*							PR					
Barn Swallow	*Hirundo rustica*							X	X	X	2	3	
Black-capped Chickadee	*Poecile atricapillus*							PO	PO				
Blue Jay	*Cyanocitta cristata*							PO	PR				
Bobolink	*Dolichonyx oryzivorus*						PO	PO	PR	PR	3	6	
Brown-headed Cowbird	*Molothrus ater*							PO					
Chipping Sparrow	*Spizella passerina*						PR						
Cedar Waxwing	*Bombycilla cedrorum*							PO					
Common Grackle	*Quiscalus quiscula*						PO	PO	PO	PO		1	
Common Yellowthroat	*Geothylpis trichas*							PR	PO	PR	1	1	
Downy Woodpecker	*Picoides pubescens*							PO					
Eastern Kingbird	*Tyrannus tyrannus*								PR	PO		1	
Eastern Meadowlark	*Sturnella magna*						PO	PO	PR	PO	2		
European Starling	*Sturnus vulgaris*								PO				
Great Crested Flycatcher	*Myiarchus crinitus*							PO					
House Wren	*Troglodytes aedon*						PR	PO		PO	1		
Indigo Bunting	*Passerina cyanea*							PO					
Killdeer	*Charadrius vociferus*								PO	PO	1		
Mallard	*Anas platyrhynchos*									X		1	
Northern Rough-winged Swal	*Stelgidopteryx serripennis*								X				
Red-tailed Hawk	*Buteo jamaicensis*								PR				
Red-winged Blackbird	*Agelaius phoeniceus*						PR	CO	PR	CO	2	4	
Ring-billed Gull	*Larus delawarensis*								PO				
Rock Pigeon	*Columba livia*									X	3		
Savannah Sparrow	*Passerculus sandwichensis*						PR	CO	PR	PR	6	4	
Song Sparrow	*Melospiza melodia*						PO	PR	CO	PO		2	
Tree Swallow	*Tachycineta bicolor*							X	X	X	1	1	
Warbling Vireo	*Vireo gilvis*							PO	PO				
Yellow Warbler	*Setophaga petechia*						PO						
Total	**31**						11	21	20	16	**22**	**27**	

APPENDIX IX

Bird Species Observed in the Study Area 2006 - 2014

Appendix IX. Bird Species Observed in the Study Area

Common Name	Scientific Name	SRANK	COSEWIC	SARO	Local Status	NRSI 2014
HERONS & BITTERNS						
Great Blue Heron	*Ardea herodias*	S4B			**	
Green Heron	*Butorides virescens*	S4B			**	(X)
GEESE						
Canada Goose	*Branta canadensis*	S5				(PO)
DUCKS						
Wood Duck	*Aix sponsa*	S5				
Mallard	*Anas platyrhynchos*	S5				PO
Bufflehead	*Bucephala albeola*	S4				
Hooded Merganser	*Lophodytes cucullatus*	S5B, S5N				
VULTURES						
Turkey Vulture	*Cathartes aura*	S5B			√	(X)
HAWKS, KITES & EAGLES						
Northern Harrier	*Circus cyaneus*	S4B	NAR	NAR	√*	
Cooper's Hawk	*Accipiter cooperii*	S4	NAR	NAR	√*	
Red-tailed Hawk	*Buteo jamaicensis*	S5	NAR	NAR		(PO)
CARACARAS & FALCONS						
American Kestrel	*Falco sparverius*	S4			√*	
PARTRIDGES, GROUSE & TURKEY						
Ruffed Grouse	*Bonasa umbellus*	S4				
Wild Turkey	*Meleagris gallopavo*	S5				
PLOVERS						
Killdeer	*Charadrius vociferus*	S5B, S5N				PO
Solitary Sandpiper	*Tringa solitaria*	S4B				(PR)
SANDPIPERS & PHALAROPES						
Spotted Sandpiper	*Actitis macularia*	S5				
American Woodcock	*Scolopax minor*	S4B				(PR)
GULLS						
Ring-billed Gull	*Larus delawarensis*	S5B, S4N				
Herring Gull	*Larus argentatus*	S5B, S5N			**	
DOVES						
Rock Pigeon	*Columba livia*	SNA				PO
Mourning Dove	*Zenaida macroura*	S5				PO
CUCKOOS						
Yellow-billed Cuckoo	*Coccyzus americanus*	S4B			√	
Black-billed Cuckoo	*Coccyzus erythropthalmus*	S5B			√*	PR
TYPICAL OWLS						
Barred Owl	*Strix varia*	S5			√	(X)
KINGFISHERS						
Belted Kingfisher	*Megaceryle alcyon*	S4B			√	CO

Common Name	Scientific Name	SRANK	COSEWIC	SARO	Local Status	NRSI 2014
WOODPECKERS						
Red-bellied Woodpecker	*Melanerpes carolinus*	S4			√	
Yellow-bellied Sapsucker	*Sphyrapicus varius*	S5B			√*	
Downy Woodpecker	*Picoides pubescens*	S5				PO
Hairy Woodpecker	*Picoides villosus*	S5			√*	
Northern Flicker	*Colaptes auratus*	S4B			√*	PO
Pileated Woodpecker	*Dryocopus pileatus*	S5			√*	
FLYCATCHERS						
Flycatcher spp						
Eastern Wood-pewee	*Contopus virens*	S4B	SC	SC		PR
Alder Flycatcher	*Empidonax alnorum*	S5B				
Willow Flycatcher	*Empidonax traillii*	S5B			√	PR
Least Flycatcher	*Empidonax minimus*	S4B			√	
Eastern Phoebe	*Sayornis phoebe*	S5B				(PO)
Great Crested Flycatcher	*Myiarchus crinitus*	S4B				PR
Eastern Kingbird	*Tyrannus tyrannus*	S4B			√*	PO
LARKS						
Horned Lark	*Eremophila alpestris*	S5B				
SWALLOWS						
Tree Swallow	*Tachycineta bicolor*	S4B				X
Bank Swallow	*Riparia riparia*	S4B			√*[1]	PO
Barn Swallow	*Hirundo rustica*	S4B	T	THR		X
Cliff Swallow	*Petrochelidon pyrrhonota*	S4B			**[2]	
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	S4B				
CROWS & JAYS						
Blue Jay	*Cyanocitta cristata*	S5				PR
American Crow	*Corvus brachyrhynchos*	S5B				PO
CHICKADEES						
Common Redpoll	*Carduelis flammea*	S4B				
Black-capped Chickadee	*Poecile atricapillus*	S5				PR
NUTHATCHES						
Red-breasted Nuthatch	*Sitta canadensis*	S5			√*	
White-breasted Nuthatch	*Sitta carolinensis*	S5				
CREEPERS						
Brown Creeper	*Certhia americana*	S5B			√*	
WRENS						
House Wren	*Troglodytes aedon*	S5B				PR
Winter Wren	*Troglodytes hiemalis*	S5B			√*	
KINGLETS						
Golden-crowned Kinglet	*Regulus satrapa*	S5B				
Ruby-crowned Kinglet	*Regulus calendula*	S4B			√	
THRUSHES						
Swainson's Thrush	*Catharus ustulatus*	S4B			√	
Hermit Thrush	*Catharus guttatus*	S5B			√	
Wood Thrush	*Hylocichla mustelina*	S4B	T		√*	
American Robin	*Turdus migratorius*	S5B				PR

Common Name	Scientific Name	SRANK	COSEWIC	SARO	Local Status	NRSI 2014
MIMIDS						
Gray Catbird	*Dumetella carolinensis*	S4B				PO
Brown Thrasher	*Toxostoma rufum*	S4B			√	
WAXWINGS						
Cedar Waxwing	*Bombycilla cedrorum*	S5B				PR
STARLINGS						
European Starling	*Sturnus vulgaris*	SNA				PO
VIREOS						
Warbling Vireo	*Vireo gilvis*	S5B				PO
Red-eyed Vireo	*Vireo olivaceus*	S5B				PR
WOOD WARBLERS						
Warbler spp.						
Tennessee Warbler	*Oreothlypis peregrina*	S5B			√	
Nashville Warbler	*Oreothlypis ruficapilla*	S5B				
Yellow Warbler	*Setophaga petechia*	S5B				PR
Chestnut-sided Warbler	*Setophaga pensylvanica*	S5B				
Yellow-rumped Warbler	*Setophaga coronata*	S5B				
Black-throated Green Warbler	*Setophaga virens*	S5B			√	
Pine Warbler	*Setophaga pinus*	S5B			√*	
American Redstart	*Setophaga ruticilla*	S5B			√*	PR
Ovenbird	*Seiurus aurocapillus*	S4B			√*	
Northern Waterthrush	*Parkesia noveboracensis*	S5B				PR
Common Yellowthroat	*Geothlypis trichas*	S5B				PR
CARDINALS & ALLIES						
Northern Cardinal	*Cardinalis cardinalis*	S5				PR
Scarlet Tanager	*Piranga olivacea*	S4B			√	
SUMMER FINCHES						
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	S4B			√*	PR
Indigo Bunting	*Passerina cyanea*	S4B				PR
SPARROWS						
Grasshopper Sparrow	*Ammodramus savannarum*	S4B			√	(PO)
American Tree Sparrow	*Spizella arborea*	S4B				
Chipping Sparrow	*Spizella passerina*	S5B				PO
Field Sparrow	*Spizella pusilla*	S4B			√*	
Vesper Sparrow	*Pooecetes gramineus*	S4B			√*	
Savannah Sparrow	*Passerculus sandwichensis*	S4B			√*	PR
Song Sparrow	*Melospiza melodia*	S5B				PR
Swamp Sparrow	*Melospiza georgiana*	S5B				
White-throated Sparrow	*Zonotrichia albicollis*	S5B				
Dark-eyed Junco	*Junco hyemalis*	S5B			√	
BLACKBIRDS						
Bobolink	*Dolichonyx oryzivorus*	S4B	T	THR	√*	PR
Red-winged Blackbird	*Agelaius phoeniceus*	S4				CO
Eastern Meadowlark	*Sturnella magna*	S4B	T	THR	√*	PO
Rusty Blackbird	*Euphagus carolinus*	S4B	SC	NAR		
Common Grackle	*Quiscalus quiscula*	S5B				PO
Brown-headed Cowbird	*Molothrus ater*	S4B				PR

Common Name	Scientific Name	SRANK	COSEWIC	SARO	Local Status	NRSI 2014
ORIOLES						
Baltimore Oriole	*Icterus galbula*	S4B			√*	PR
WINTER FINCHES						
House Finch	*Carpodacus mexicanus*	SNA				
Pine Siskin	*Spinus pinus*	S4B				
American Goldfinch	*Spinus tristis*	S5B				PR
OLD WORLD SPARROWS						
House Sparrow	*Passer domesticus*	SNA				
					Total Observed	**51**

Legend
* Incidental birds recorded during other surveys
(breeding evidence) Species and breeding evidence recorded outside of point count

SRANK
S1 Critically Imperiled
S2 Imperiled
S3 Vulnerable
S4 Apparently Secure
S5 Secure
? Rank Uncertain
S#S# Range Rank —Numeric range rank (e.g., S2S3) used to indicate any range of uncertainty about the status of the species

B Breeding
SZ Not of practical conservation concern
SE Exotic
SAN Non-breeding accidental
SZN Non-breeding migrants/vagrants

COSEWIC, SARO Codes
E, END Endangered
T, THR Threatened
SC Special Concern
NAR Not at Risk

Local Status (Wellington) (Dougan 2009)
√ Significant and rare
√* Significant but not rare
** Only habitats that support or have recently supported active nests should be considered signficant
[1] Only significant in nesting colonies of >100
[2] Only significant in nesting colonies >8

Breeding Evidence Codes
X Observed
PO Possible breeder
PR Probable breeder
CO Confirmed breeder

APPENDIX X

Herpetofaunal Species Observed in the Subject Property

Appendix X. Herptofauna Species Observed in the Study Area

Common Name	Scientific Name	SRANK	COSEWIC	SARO	NRSI									
					1998-2004	2006	2007	2008	2009	2010	2011	2012	2013	2014
Turtles														
Common Snapping Turtle	*Chelydra serpentina serpentina*	S5	SC		√									
Midland Painted Turtle	*Chrysemys picta marginata*	S5								√	√			
Snakes														
Eastern Milksnake	*Lampropeltis t. triangulum*	S3	SC	SC										
Eastern Gartersnake	*Thamnophis sirtalis sirtalis*	S5			√					√	√		√	
Northern Brownsnake	*Storeria dekayi dekayi*	S5	NAR	NAR						√				
Northern Red-belied Snake	*Storeria occipitomaculata occipitomaculata*	S5								√				
Salamanders														
Jefferson/Blue-spotted Salamdander Polyploids	*Ambystoma jeffersonianum-laterale polyploids*	S2									√			
Eastern (Northern) Redback Salamander	*Plethodon cinereus*	S5			√				√					
Toads and Frogs														
American Toad	*Bufo americanus*	S5								√	√	√	√	√
Tetraploid Gray Treefrog	*Hyla versicolor*	S5			√	√	√	√	√	√	√	√	√	√
Western Chorus Frog*	*Pseudacris triseriata* pop.2	S3	T	NAR	√	√								
Northern Spring Peeper	*Pseudarcris crucifer crucifer*	S5					√	√	√	√	√	√	√	√
Bullfrog	*Rana catesbeiana*	S4			√	√	√	√	√	√				
Green Frog	*Rana clamitans melanota*	S5								√		√	√	√
Pickerel Frog	*Rana palustris*	S4	NAR	NAR	√	√	√	√	√	√				
Northern Leopard Frog	*Rana pipiens*	S5	NAR	NAR						√	√		√	√
Mink Frog	*Rana septentrionalis*	S5			√	√			√	√				
Wood Frog	*Rana sylvatica*	S5			√		√	√	√	√	√	√	√	√

*Great Lakes/ St. Lawrence - Canadian Shield Pop.

Legend	
SRANK	
S2 Imperiled	S4 Apparently Secure
S3 Vulnerable	S5 Secure
COSEWIC, SARO	
NAR Not at Risk	SC Special Concern
T/THR Threatened	
NRSI	
√ Observed	

APPENDIX XI

Amphibian Species Observed by Plot 2006 - 2014

Appendix XI. Amphibian Species Observed by Plot 2006 - 2014

Station #1

	2006	2007			2008			2009			2010			2011			2012			2013			2014		
	Calling	Calling			Calling			Calling			Calling			Calling			Calling			Calling			Calling		
COMMON NAME	June 22	April 29	May 16	June 5	April 24	May 15	June 4	April 23	May 11	June 2	April 24	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 17	May 9	June 10	April 29	May 21	June 9
American Toad	Nothing Heard			Nothing Heard			Nothing Heard		Nothing Heard				Nothing Heard	1 (1)			Nothing Heard	Nothing Heard	Nothing Heard						
Northern Spring Peeper		3	1 (4)		3	1 (5)		1 (4)			1 (7)	2 (7)		3	1 (10)					3	2 (6)		3	1 (4)	
Tetraploid Gray Treefrog										1 (1)						1 (1)					2 (3)				3
Western Chorus Frog																									
Northern Leopard Frog																									
Pickerel Frog																									
Green Frog																									
Mink Frog																									
Bullfrog																									
Wood Frog		1 (7)						1 (1)						2 (10)						2 (3)			1 (1)		
Beaufort Wind Scale	0	5	0	1	0	0	3	1	0	2	1	2	2	3	3	1	1	3	2	1	0		4	1	1
%Cloud Cover	98	98	100	25	65	100	100	10	5	15	5	100	100	20	100	5	100	35	100	70	10		20	100	0
Air temp. (°C)	21	13	10	10	7	9	16	2	3	12	10	10	18	15	13	12	12	16	12	6	15		5	15	17.5
Water temp. (°C)	19.9	8.0	10.1	10.3	N/A	N/A	11.8	3.4	6.2	10.5		7.7		13	12	11.6	N/A	N/A	N/A	5.6	11.2		5	10.3	12.8
Water pH	7.2	7.4	7.1	7.2	N/A	N/A	8.2	9.1	8.6	9.4		6.5		N/A	7.6	7.5	N/A	N/A	N/A	7.4	7.3		7.4	7.4	8
Precipitation?	None	Light rain	Very light rain	None	None	None	None	None	None	None	None	Light rain	None	None	Moderate Rain	None	None	None	None	None	None		None	None	None

Notes:
2006
fair shallow water
Leopard frog heard at this site during veg survey on 06/21/06
2007
A lot of SPPE and American Toad calling from wetlands/wet areas in Ag field
Wood cock heard
2008
a lot of air traffic on May 15
gray treefrogs heard calling from a distance on June 4th
2009
May 11 - spring peeper heard in distance
2010
Apr 24 - No water
May 13 - woodcock calling within study area
2011
Apr 27 - Woodcock calling
June 2 - Woodcock heard
2012
Apr 19 - spring peeper (call code 3) heard at pond beside abandoned house, no water
May 15 - spring peeper and gray treefrog heard beyond point count
Jun 4 - American robin, gull sp., bat sp., traffic noise from Hanlon Parkway
2013
Apr 16 - American woodcock in field to south
May 9 - AMTO and GRTR calling outside of plot
2014
Apr 29 - traffic noise from Hanlon expressway

Station #2	2006	2007			2008			2009			2010			2011			2012			2013			2014		
	Calling	Calling			Calling			Calling			Calling			Calling			Calling			Calling			Calling		
COMMON NAME	June 22	April 29	May 16	June 5	April 24	May 15	June 4	April 23	May 11	June 2	April 24	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10	April 29	May 21	June 9
American Toad	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard		Nothing Heard
Northern Spring Peeper					1 (2)							1 (4)													
Tetraploid Gray Treefrog																								1 (3)	
Western Chorus Frog																									
Northern Leopard Frog																									
Pickerel Frog																									
Green Frog																									
Mink Frog																									
Bullfrog																									
Wood Frog																									
Beaufort Wind Scale	2	4	2	1	1	0	4	1	0	2	0	2	0	3	3	0	1	0	2	1	0		3	1	1
%Cloud Cover	98	98	100	25	65	100	100	20	10	25	10	100		20	100	5	100	35	100	0	10		20	100	0
Air temp. (°C)	23	12	10	10	7	11	17	2	4	12	13	10	18	15	12.5	12	13	16	12	5.5	13		8	22	20
Water temp. (°C)		10.0	12.1	11.7	7	7.8	13.2	5.2	6.3	8.5	8.6	6.9	11.3	9	8.7	8.1	N/A	N/A	N/A	3.6	N/A		5	9.2	13
Water pH		7.6	7.5	7.3	N/A	7.9	8.3	8.4	8.5	9.8	7.6	6.7	8.5	N/A	7.9	7.6	N/A	N/A	N/A	7.9	N/A		7.7	7.7	8.3
Precipitation?	None	None	None	None	None	None	None	None	None	None	None	Light rain	None	None	Moderate Rain	None	None	None	Light rain	None	None		None	None	None

Notes:
2006
No standing water, fairly dry site
2007
American Woodcock heard displaying
2008
Spring Peepers heard outside study area on Apr. 24th
2009
April 23 - one leopard frog heard from behind
May 11 - 2 spring peepers heard from beyond point count
2010
April 24 - Mallard observed, 8 bats observed foraging over creek/woodlot
June 3 - Gray Treefrog heard outside study area
2011
Apr 27 - American Woodcock calling during point counts, Wild Turkey roosting
2012
Apr 19 - American Woodcock calling, no water in ditch to east
May 15 - gray treefrog heard beyond point count
Jun 4 - Gray Treefrog 2(2) 0° heard beyond point count, American Toad in SWM pond
2013
May 9 - no water
2014
Apr 29 - Spring peeper chorus heard south of woodlot beyond plot, incidental: Killdeer
May 21 - incidental: American Woodcock

Station #4	2006	2007			2008			2009			2010			2011			2012			2013			2014		
	Calling	Calling			Calling			Calling			Calling			Calling			Calling			Calling			Calling		
COMMON NAME	June 22	April 29	May 16	June 6	April 24	May 15	June 4	April 23	May 11	June 2	April 22	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10	April 29	May 21	June 9
American Toad	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard		1 (1)	Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard	2 (2)	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard		
Northern Spring Peeper					3				1 (2)								1 (1)								
Tetraploid Gray Treefrog																									
Western Chorus Frog																									
Northern Leopard Frog																								1 (1)	
Pickerel Frog																									
Green Frog																									1 (2)
Mink Frog																									
Bullfrog																									
Wood Frog														1 (1)											
Beaufort Wind Scale	1	3	2	1	1	1	1	1	0	1	0	2	0	3	2	0	1	0	1	0	0		3	1	0
%Cloud Cover	80	20	100	20	65	5	100	40	40	50	5	100	100	40	100	5	100	0	100	60	15		5	0	90
Air temp. (°C)	20	14	10	9	12	17	16	5	8	16	5	8	24	15	14	12	12	22	15	7	15		7.5	20	19
Water temp. (°C)		11.4	11.5	11.2	9	10.5	14.5	7.1	9.1	11.8	6.2	6		10	N/A	8.1	N/A	N/A	N/A	4.8	N/A		5.5	18.8	10.4
Water pH		7.6	7.7	7.6	N/A	7.8	8.3	8.2	9.3	9	7.8	7.6		N/A	N/A	7.6	N/A	N/A	N/A	8.1	N/A		7.2	8	8.2
Precipitation?	None	None	None	None	None	None	None	None	None	None	None	Rain	None	None	Rain	None	Light rain	None	None	None	None		None	None	None

Notes:
2006
No standing water
2007
Water extremely shallow
A lot of SPPE and American toads calling from wet areas in Ag field away from woodlot
American woodcock displaying in field near entrance to PC
2008
Spring peepers heard calling all around area on April 24th
2009
June 2 - gray treefrog heard beyond point count
2010
Spring peepers (2) heard beyond point count
Conducted on edge on reed canary marsh and edge of white cedar forest
2011
Apr 27 - Spring Peepers, call code 3 (lots), and American Toad call code 2 at 270°
2012
May 15 - gray treefrog and spring peeper heard beyond point count. American robin, American woodcock, bat sp.
Jun 4 - American toad and gray treefrog heard beyond point count
2013
Apr 16 - Patchy shallow water, SPPE and WOFR heard west of Downey Road
May 9 - no water present, SPPE calling from southeast at 150m, American robin calling
2014
Apr 29 - SPPE heard in far distance, rain early in day

Station #6	2006	2007			2008			2009			2010			2011			2012			2013			2014		
	Calling	Calling			Calling			Calling			Calling			Calling			Calling			Calling			Calling		
COMMON NAME	June 22	April 29	May 16	June 6	April 24	May 15	June 4	April 23	May 11	June 2	April 22	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10	April 29	May 21	June 9
American Toad	Nothing Heard	1(4)		Nothing Heard					Nothing Heard				Nothing Heard	1 (6)		Nothing Heard	Nothing Heard	Nothing Heard					Nothing Heard	Nothing Heard	
Northern Spring Peeper		3	2(3)		1 (2)	1(1)	1(2)	3			3	2 (5)		3	3				1 (1)	2 (4)	1 (2)				
Tetraploid Gray Treefrog							3			1 (1)															1 (2)
Western Chorus Frog		1(1)																							
Northern Leopard Frog																									
Pickerel Frog																									
Green Frog							1(2)			1 (1)															
Mink Frog																									
Bullfrog																									
Wood Frog														1 (2)						3					
Beaufort Wind Scale	1	3	2	1	1	0	3	0	0	0	1	1	0	1	3	1	2	0	2	1	1		3	1	0
%Cloud Cover	2	40	100	20	65	100	100	30	10	50	10	100	100	40	100	0	100	0	100	70	5		5	0	90
Air temp. (°C)	18	12	9	9	11	13	16	2	5	15	8	8	24	14	13.5	12	11	19	15	6	13		7.5	20	17
Water temp. (°C)	23.6	14.4	14.1	15.3	N/A	13.8	16.3	8.9	7.7	16.7	13.3	9	19.1	13.5	N/A	10	N/A	N/A	N/A	10.5	N/A		6.7	N/A	N/A
Water pH	7.8	7.8	7.8	7.6	N/A	8.0	8.5	8.1	8.7	9.8	7.9	8.5	7.2	N/A	N/A	8.3	N/A	N/A	N/A	7.4	N/A		8.1	N/A	N/A
Precipitation?	None	None	None	None	None	None	None	None	None	None	None	None	None	None	Rain	None	Light rain	None	None	None	None		None	None	None

Notes:
2006
Green frog observed
Appears to be wettest area on study site
2007
Wetland was filled in last year but has somewhat re-established itself
Quite a few frogs calling in area and surrounding wet pockets
Water level higher than last year in this area
2008
large number of treefrogs calling on June 4th
wetland has expanded in size since last year and is starting to naturalize after being plowed in 2 years ago.
2009
April 23 - wood frog heard after point count
May 11 - spring peeper heard in distance
2010
Station at tree at edge of marsh. Location flagged
American woodcock to east of pond
2011
Apr 27 - American Toad (lots) at 230°
May 18 - American Woodcock 100m at 20°; Spring Peepers 3 at 150m and 225°
2012
Apr 19 - American woodcock 200m @ 160°
May 15 - American toad and gray treefrog heard beyond point count
Jun 4 - American toad and gray treefrog heard beyond point count
2013
Apr 16 - Mallard pair
May 9 - highway noise, no standing water present, damp soils in cattail marsh, GRTR in SWM pond to NW
2014
Apr 29 - water and pH taken in puddle, rain early in day
May 21 - no standing water

Station #7

	2006	2007			2008			2009			2010			2011			2012			2013			2014		
	Calling	Calling			Calling			Calling			Calling			Calling			Calling			Calling			Calling		
COMMON NAME	June 22	April 29	May 16	June 6	April 24	May 15	June 4	April 23	May 11	June 2	April 22	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10	April 29	May 21	June 9
American Toad	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard	Nothing Heard
Northern Spring Peeper						1(1)																			
Tetraploid Gray Treefrog																									
Western Chorus Frog																									
Northern Leopard Frog																									
Pickerel Frog																									
Green Frog																									
Mink Frog																									
Bullfrog																									
Wood Frog																									
Beaufort Wind Scale	1	3	2	1	1	0	2	0	0	0	1	1	0	1	1	2	1	0	2	1	0		3	1	0
%Cloud Cover	75	15	100	20	65	50	100	30	10	50	0	100	100	10	100	0	100	0	100	80	15		5	0	90
Air temp. (°C)	18	13	10	7	11	13	16	4	7	15	8	8	24	13	14	13	12	20	15	7	14		7.5	20	18
Water temp. (°C)	11.4	9.3	10.5	10.4	N/A	10.9	10.8	5.9	n/a	12	8.6	6		8	9.5	11.6	7.6	N/A	N/A	5.3	7.7		5.4	8.5	11.9
Water pH	8.2	7.7	7.7	7.6	N/A	8.2	8.4	8	n/a	9.7	7.6	7.9		N/A	8	8.4	7.8	N/A	N/A	8.1	8.6		7.3	7.8	7.8
Precipitation?	None	None	None	None	None	None	None	None	None	None	None	None	None	None	Rain	None	Light rain	None	None	None	None		None	None	None

Notes:
2006
Small shallow stream
2008
Spring peepers calling from all around, but not within study boundary on April 24th
No open water on April 24th
2009
May 11 - no standing water
2010
April 22 - American woodcock in field, 2 spring peepers in far distance
June 3 - No water present
2012
Apr 19 - American toad call code 3 beyond 100m at 0° in SWM pond
May 15 - gray treefrog and green frog heard beyond point count
Jun 4 - spring peeper, gray treefrog and American toad heard beyond point count
2013
Apr 16 - Agitated raccoon calling, SPPE 250m to south
May 9 - SPPE to west, GRTR to southeast at 200m, mourning dove calling
2014
Apr 29 - rain earlier in day
June 9 - incidental: 2 barred owls heard >100m away, at 160°

Station #8

COMMON NAME	2006 Calling	2007 Calling			2008 Calling			2009 Calling			2010 Calling			2011 Calling			2012 Calling			2013 Calling			2014 Calling		
	June 22	April 29	May 16	June 6	April 24	May 15	June 4	April 23	May 11	June 2	April 22	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10	April 29	May 21	June 9
American Toad	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard	Nothing Heard				
Northern Spring Peeper																									
Tetraploid Gray Treefrog																		1 (1)							
Western Chorus Frog																									
Northern Leopard Frog																									
Pickerel Frog																									
Green Frog																									
Mink Frog																									
Bullfrog																									
Wood Frog																									
Beaufort Wind Scale	1	2	2	1	1	0	1	0	0	1	1	2	0	2	2	1	1	1	2	0	0				
%Cloud Cover	80	15	100	20	65	50	100	30	30	50	0	100	100	40	100	0	100	5	100	80	15				
Air temp. (°C)	18.5	13	10	9	11	14	16	3	7	16	8	8	24	14	13	13	12	22	15	7	14				
Water temp. (°C)	14.5	11.5	11.4	11	10	12.1	13	7.6	8.9	12.4	9.4	7	13.6	12	12	13	12.9	N/A	N/A	7	14.6				
Water pH	8	7.7	7.8	7.8	N/A	8.2	8.5	8.1	9.4	9.4	7.6		7.1	N/A	8.4	8.4	8.4	N/A	N/A	8.4	8.4				
Precipitation?	None	None	None	None	None	None	None	None	None	None	None	None	None	None	Rain	None	Light rain	None	None	None	None				

Notes:
2006
Small, shallow stream
2007
Water moving quickly in this area, may not be prime amphibian breeding habitat
2008
Spring peepers heard very far out of study area
2010
April 22 - American Robin, American woodcock
2011
Apr 27 - American Toad observed corssing pathway enroute to Plot 008; Killdeer; Spring peepers and American toads (a lot) at 270 °
2012
Apr 19 - American toad and spring peeper both call code 3, 150m at 270°
May 15 - spring peeper heard beyond point count
Jun 4 - gray treefrog and American toad heard beyond point count
2013
Apr 16 - benthics observed in watercourse
May 9 - SPPE, AMTO and GRTR in SWM ponds to west
2014
Apr 29 - rain earlier in day
June 9 - incidental: fireflies

Station #9	2007			2008			2009			2010			2011			2012			2013			2014		
	Calling			Calling			Calling			Calling			Calling			Calling			Calling			Calling		
COMMON NAME	April 29	May 16	June 6	April 24	May 15	June 4	April 23	May 11	June 2	April 24	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10	April 29	May 21	June 9
American Toad				Nothing Heard		3					Nothing Heard	Nothing Heard	1 (1)			Nothing Heard	Nothing Heard	Nothing Heard						Nothing Heard
Northern Spring Peeper	2(10)	1(2)			1(3)		1 (7)	1 (4)		1 (1)			1 (2)	1 (4)					1 (2)	2 (5)		3	1 (5)	
Tetraploid Gray Treefrog						1 (1)			1 (2)															
Western Chorus Frog																								
Northern Leopard Frog							1 (1)																	
Pickerel Frog																								
Green Frog			1(1)																					
Mink Frog																								
Bullfrog																								
Wood Frog	1(2)						1 (4)						1 (2)											
Beaufort Wind Scale	5	2	1	1	0	1	0	0	2	0	2	0	3	3	2	1	3	2	1	0		4	1	1
%Cloud Cover	70	100	20	65	50	100	10	20	25	5	100	100	20	100	5	100	40	100	80	10		35	100	0
Air temp. (°C)	13	10	9	11	14	16	2	6	14	1	10	18	15	9.4	11	12	16	12	5	16		5	22	18
Water temp. (°C)	12.5	12.2	13.7	10	12.1	13	5.4	7.7	14.3	8.5			N/A	N/A	12.9	N/A	N/A	N/A	6.3	14.5		5.2	17.6	N/A
Water pH	7.7	7.5	7.3	N/A	8.2	8.5	8.2	8.7	9.6	8			N/A	N/A	6.6	N/A	N/A	N/A	7.5	7.6		7.4	7.6	N/A
Precipitation?	None	None	None	None	None	None	None	None	None	None	Rain	None	None	Heavy Rain	None	Light rain	None	None	None	None		None	None	None

Notes:
2007
SPPE and American toad abundant in wetland across road (Downey)
2008
Spring peepers heard very far out of study area
2010
May 13 - no standing water
2011
Apr 27 - Could not appraoch to take water temperature
May 18 - No standing water for temperature/pH; hard to hear because of the rain
Jun 2 - American Bittern on west side of road about 5 minutes before survey (offsite, west of Downey Rd); 1 gray treefrog heard beyond 100m plot radius.
2012
Apr 19 - spring peepers and American toad heard beyond point count west of Downy Rd.
May 15 - spring peepers and gray treefrog beyond point count
Jun 4 - gray treefrog heard beyound point count, 300m at 45°
2013
Apr 16 - manure being spread in field to south
May 9 - raccoon observed in tree in wetland
2014
Apr 29 - American woodcock in field/meadow east of plot, observed doing aerial display
June 9 - No standing water

Station #10

	2009			2010			2011			2012			2013			2014		
	Calling			Calling			Calling			Calling			Calling			Calling		
COMMON NAME	April 23	May 11	June 2	April 22	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10	April 29	May 21	June 9
American Toad		Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard		Nothing Heard	Nothing Heard			Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard	Nothing Heard
Northern Spring Peeper					1 (2)					1 (1)	1 (1)							
Tetraploid Gray Treefrog																		
Western Chorus Frog																		
Northern Leopard Frog																		
Pickerel Frog																		
Green Frog																		
Mink Frog																		
Bullfrog																		
Wood Frog	1 (2)						1 (2)											
Beaufort Wind Scale	0	0	2	0	2	0	3	4	3	1	3	2	1	0		3	1	0
%Cloud Cover	20	10	15	5	100	100	90	100	5	100	40	100	60	10		35	100	90
Air temp. (°C)		3	12	4	10	24	14.5	13.8	12	13	16	12	5	13		5	15	17
Water temp. (°C)	8.5	10.7	14.1	12.1	9.3	19	12	13.1	16.5	14.3	17	N/A	9.3	18.9		8.4	17.9	15
Water pH	8.8	8.6	9.5	7.8	7	7.4	N/A	8	8.1	7.6	8.2	N/A	7.9	7.9		N/A	8	7.7
Precipitation?	None	None	None	None	Light rain	None	None	Moderate Rain	None	None	None	None	None	None		None	None	None

Notes:

2011
May 18 - Wood frog on road

2012
May 15 - spring peeper 2(3) and gray treefrog 3 heard beyond point count at 315°, mallards present

Jun 4 - noise from road traffic and Sleeman's

2013
May 9 - SPPE 1(1) beyond point count at 125m, GRTR chorus on south side of road in distance

2014
Apr 29 - Moderate traffic noise from Hanlon expressway, quite a bit of water in pond

June 9 - 1 Green frog observed at edge of pond (not calling)

Station #11

	2009			2010			2011			2012			2013			2013		
	Calling			Calling			Calling			Calling			Calling			Calling		
COMMON NAME	April 23	May 11	June 2	April 22	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10	April 29	May 21	June 9
American Toad		Nothing Heard	Nothing Heard			Nothing Heard			Nothing Heard		Nothing Heard	Nothing Heard					Nothing Heard	Nothing Heard
Northern Spring Peeper	1 (1)			1 (1)	2 (5)		1 (4)	1 (4)		2 (5)			1 (1)	1 (1)		1 (1)		
Tetraploid Gray Treefrog																		
Western Chorus Frog																		
Northern Leopard Frog	1 (1)																	
Pickerel Frog				1 (1)														
Green Frog																		
Mink Frog																		
Bullfrog																		
Wood Frog	1 (1)																	
Beaufort Wind Scale	0	0	2	0	2	0	3	4	1	1	3	2	1	0		3	1	0
%Cloud Cover	20	10	25	5	100	100	40	100	5	100	40	100	60	10		40	100	90
Air temp. (°C)	3	3	12	4	10	24	14.5	13	12	13	16	12	5	13		6	16	17
Water temp. (°C)	6.6	n/a	n/a	6	9.5		12	12	14.3	14.5	16.7	N/A	8.2	18.6		6.5	18.1	16
Water pH	7.8	n/a	n/a	8.1	7.8		N/A	7.1	8.0	7.8	8	N/A	7.9	7.8		7.9	7.7	7.6
Precipitation?	None	None	None	None	Light rain	None	None	Moderate Rain	None	None	None	None	None	None		None	None	None

Notes:
2012
May 15 - Gray treefrog (call code 3) heard beyond point count
Jun 4 - traffic noise from Hanlon Parkway and Sleeman's
2013
Apr 16 - raccoon observed
2014
Apr 29 - alot of rain earlier in day, incidentals: killdeer, eastern meadowlark

Station #12

	2009			2010			2011			2012			2013			2014		
	Calling			Calling			Calling			Calling			Calling			Calling		
COMMON NAME	April 23	May 11	June 2	April 22	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10	April 29	May 21	June 9
American Toad						Nothing Heard			Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard						
Northern Spring Peeper	3	1 (3)		1 (6)	3		3	3					3	3		2 (6)	1 (1)	
Tetraploid Gray Treefrog																	1 (3)	1 (2)
Western Chorus Frog																		
Northern Leopard Frog	1 (2)																	
Pickerel Frog																		
Green Frog			1 (2)															
Mink Frog																		
Bullfrog																		
Wood Frog	1 (2)						1 (2)						1 (1)					
Beaufort Wind Scale	0	0	2	2	2	0	4	4	2	1	3	2	2	0		3	1	1
%Cloud Cover	20	10	15	30	100		50	100	0	100	15	100	70	10		10	100	0
Air temp. (°C)	2	3	10	5	10		14.5	13.5	10	10.5	16	12	7	12		5	15	17.5
Water temp. (°C)	6.9	11.5	14.6	11.1	10.4	19.8	N/A	N/A	10	N/A	N/A	N/A	9.7	12.3		N/A	13.4	N/A
Water pH	8	9.2	9.9	7.8	6.8	8	N/A	N/A	8.4	N/A	N/A	N/A	7.4	7.5		N/A	7.5	N/A
Precipitation?	None	None	None	None	Light rain	None	None	Moderate Rain	None	Light rain	None	None	None	None		None	None	None

Notes:
2010
April 22 - Spring peeper behind us. Spring peeper making trill sound
June 3 - Very little water
2011
Apr 27 - AMTO observed crossing Downey Rd near Forestell (moving west); AMTO calling behind us
May 18 - No standing water for temperature/pH; road noise; Incidental - American Woodcock
2012
Apr 19 - no standing water present, incidental observation of wood frog
May 15 - no standing water present American toad >300m to south
Jun 4 - traffic noise from Hanlon Parkway
2013
Apr 16 - west pond completely dry, middle pond small puddles, east pond with a small pool (depth 15cm)
May 9 - AMTO in distance to east
2014
Apr 29 - No standing water in west portion of wetland, some moist pockets, alot of traffic noise from Hanlon expressway
May 21 - incidental: killdeer
June 9 - No standing water at station

Station #13

COMMON NAME	2009 Calling			2010 Calling			2011 Calling			2012 Calling			2013 Calling			2014 Calling		
	April 23	May 11	June 2	April 22	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10	April 29	May 21	June 9
American Toad	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard	Nothing Heard
Northern Spring Peeper																		
Tetraploid Gray Treefrog																		
Western Chorus Frog																		
Northern Leopard Frog																		
Pickerel Frog																		
Green Frog																		
Mink Frog																		
Bullfrog																		
Wood Frog																		
Beaufort Wind Scale	0	0	0	1	1	0	1	2	1	2	0	1	0	1		3	1	0
%Cloud Cover	30	10	50	10	100	100	30	100	0	90	0	100	60	5		5	0	90
Air temp. (^{o}C)	3	5	14	5	8	24	14	13	12	10	17	15	6	13		7	21	17
Water temp. (^{o}C)	6.2	8	11.3	6.6	8	14.5	11	N/A	12	N/A	N/A	N/A	N/A	N/A		5.9	N/A	N/A
Water pH	8	8.8	9.9	7.8	7.9	7.2	N/A	N/A	8.2	N/A	N/A	N/A	N/A	N/A		7.6	N/A	N/A
Precipitation?	None	None	None	None	None	None	None	None	None	None	None	None	None	None		None	None	None

Notes:
2010
April 22 - Spring peeper 1(3) heard further N
2011
Apr 27 - Wood Frog at 160° (wetland on south side of road)
May 18 - Spring Peepers 200m at 15° (Station 6?)
2012
Apr 14 - American woodcock 200m at 45°, American toad (call code 3) 200m at 200°
May 15 - American toad, spring peeper and gray treefrog heard beyond point count
Jun 4 - gray treefrog and spring peeper heard beyond point count
2013
Apr 16 - SPPE to NW at 200m (call code 3), American robin and blue jay calling
May 9 - no standing water, GRTR and SPPE calling from SWM pond to south of Laird Road, American woodcock calling
2014
Apr 29 - rain earlier in day, water temperature and pH taken at culvert
May 21 - No water present, American woodcock calling
June 9 - No water present

Station #14

	2009			2010			2011			2012			2013			2014		
	Calling			Calling			Calling			Calling			Calling			Calling		
COMMON NAME	April 23	May 11	June 2	April 22	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10	April 29	May 21	June 9
American Toad	Nothing Heard	Nothing Heard	1 (1)	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard	Nothing Heard			Nothing Heard		Nothing Heard
Northern Spring Peeper										2 (2)							2 (6)	
Tetraploid Gray Treefrog																		
Western Chorus Frog																		
Northern Leopard Frog																		
Pickerel Frog																		
Green Frog																		
Mink Frog																		
Bullfrog																		
Wood Frog																		
Beaufort Wind Scale	0	0	0	0		0	1	N/A	1	1	0	2	0			3	1	0
%Cloud Cover	20	10	50	5	100	100	30	100	0	90	0	100	50			5	0	90
Air temp. (°C)	2	5	14	5		24	15	13	12	11	17	12	7			7	18	17
Water temp. (°C)	6.6	8.8	n/a	7.1	7	13.7	N/A	N/A	12	N/A	N/A	N/A	N/A			6.9	N/A	N/A
Water pH	8	8.5	n/a	8.1	8	7.4	N/A	N/A	8.5	N/A	N/A	N/A	N/A			7.8	N/A	N/A
Precipitation?	None	None	None	None	None	None	None	None	None	None	None	Light rain	None			None	None	None

Notes:
2010
Apr 22 - Spring peeper heard behind in mansion pond 1 (3)
June 3 - 3 gray treefrogs heard outside station
2011
Apr 27 - Spring Peepers at 250° on south side of road and 2 (4) heard outside plot radius
May 18 - Spring Peepers 200m at 0°; American Woodcock 150m at 45°; dead American Toad on road facing south, at culvert
2012
Apr 19 - American toad 1(1) 150m at 160°
May 15 - American toad and gray treefrog heard beyond point count
Jun 4 - gray treefrog heard beyond point count
2013
Apr 16 - no water present, eastern cottontail tracks
2014
Apr 29 - rain earlier in day, good clear flow in creek
May 21 - no water present at the roadside

Station #15

COMMON NAME	2009 Calling April 23	2009 Calling May 11	2009 Calling June 2	2010 Calling April 22	2010 Calling May 13	2010 Calling June 3	2011 Calling April 27	2011 Calling May 18	2011 Calling June 2	2012 Calling April 19	2012 Calling May 15	2012 Calling June 4	2013 Calling April 16	2013 Calling May 9	2013 Calling June 10	2014 Calling April 29	2014 Calling May 21	2014 Calling June 9
American Toad	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard					Nothing Heard		Nothing Heard	Nothing Heard					Nothing Heard	
Northern Spring Peeper					1(3)		3	2 (4)		3			1 (1)			2 (4)		
Tetraploid Gray Treefrog						2 (3)												
Western Chorus Frog																		
Northern Leopard Frog																		
Pickerel Frog																		
Green Frog																		1 (5)
Mink Frog																		
Bullfrog																		
Wood Frog													1 (1)			1 (1)		
Beaufort Wind Scale	0	0	0	0	2	0	3	2	0	1	0	1	0			3	0	0
%Cloud Cover	20	10	50	5	100	100	40	100	0	100	0	100	50			5	0	90
Air temp. (°C)	2	5	14	5	10	24	15	13	14	12	16	12	7			7	18	17
Water temp. (°C)	5.7	8.3	10.4		8.9	17.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A			6.2	17.3	N/A
Water pH	8	9	9.8		7.2	6.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A			7.9	7.9	N/A
Precipitation?	None	None	None	None	Light rain	None	None	Hard Rain	None	Light rain	None	None	None			None	None	None

Notes:
2010
April 22 No water
2011
Apr 27 - American Toad (2) observed crossing pedestrian path
June 2 - No water at the siteNothing Heard Nothing Heard
2012
Apr 19 - American woodcock 50m at 330°
May 15 - gray treefrog heard beyond point count
Jun 4 - gray treefrogs heard beyond point count
2013
Apr 16 - no standing water
2014
Apr 29 - rain earlier in day

Station #16

	2009			2010			2011			2012			2013			2014		
	Calling			Calling			Calling			Calling			Calling			Calling		
COMMON NAME	April 23	May 11	June 2	April 22	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10	April 29	May 21	June 9
American Toad		Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard			Nothing Heard	2 (2)	Nothing Heard	2 (3)						
Northern Spring Peeper	3			1 (3)			2 (4)	3					2 (3)			1 (1)	1 (1)	
Tetraploid Gray Treefrog												2 (6)						
Western Chorus Frog																		
Northern Leopard Frog																		
Pickerel Frog																		
Green Frog																		
Mink Frog																		
Bullfrog																		
Wood Frog							2 (8)						3					
Beaufort Wind Scale	0	0	0	1	1	0	2	2	1	2	0	1	0					
%Cloud Cover	30	10	50		100	100	10	100	0	100	0	100	80					
Air temp. (°C)	4	7	16	8	8	24	14	13.5	13	11	20	16	6					
Water temp. (°C)	7.5	8.8	13.7	11.2	7.5		14	13.7	11.2	N/A	N/A	N/A	9.4					
Water pH	8.1	9.1	9.5	7.5	7.9		N/A	8.1	8.4	N/A	N/A	N/A	7.9					
Precipitation?	None	None	None	None	None	None	None	Hard Rain	None	Light rain	None	None	None					

Notes:
2009
June 2 - one gray treefrog heard beyond point count
2010
June 3 - No water present
2011
Apr 27 - Spring peepers at 180°
2012
Apr 19 - American robin heard
May 15 - gray treefrog heard beyond point count
Jun 4 - gray treefrog and American toad heard beyond point count
2013
Apr 16 - traffic noise from parkway, killdeer calling
2014
Apr 29 - rain earlier in day, SPPE heard in ditch
May 21 - significant number of GRTR, SPPE and AMTO calling in SWM pond to west of station (n=30)
June 9 - GRTR full chorus (call code 3) heard from construction area (pond?) at >100m, 250°

Station #17

	2009			2010			2011			2012			2013			2014		
	Calling			Calling			Calling			Calling			Calling			Calling		
COMMON NAME	April 23	May 11	June 2	April 24	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10	April 29	May 21	June 9
American Toad		No Datasheet	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard			Nothing Heard		Nothing Heard
Northern Spring Peeper																	1 (2)	
Tetraploid Gray Treefrog																	1 (2)	
Western Chorus Frog																		
Northern Leopard Frog																		
Pickerel Frog																		
Green Frog																		
Mink Frog																		
Bullfrog																		
Wood Frog	1 (2)						1 (5)											
Beaufort Wind Scale	0		2	0	2	0	3	3	1	1	3	2	0			4	1	1
%Cloud Cover	10		25	10	100	100	20	100	10	100	40	100	0			30	100	0
Air temp. (°C)			12	12	10	18	15	13.2	12	11	16	12	6			6	22	20
Water temp. (°C)	6.3		n/a	15	8		12	12.5	N/A	N/A	N/A	N/A	8.5			6.2	18.6	N/A
Water pH	8.2		n/a	7.9	6.9		N/A	8.1	N/A	N/A	N/A	N/A	7.8			7.4	8	N/A
Precipitation?	None		None	None	Rain	None	None	Heavy Rain	None	None	None	Light rain	None			None	None	None

Notes:
2009
June 2 - no water
2011
Apr 27 - A White-tailed deer in field east of station; Red-winged blackbird; SPPE calling in distance
May 18 - Hard to hear with rain
Jun 2 - No open water
2012
Apr 19 - no standing water
May 15 - no standing water
2014
Apr 29 - incidental: mallards, pH meter malfunction (possible data inaccuracies)
May 21 - incidental: American woodcock
June 9 - no standing water present

Station #18

COMMON NAME	2011 Calling April 27	2011 Calling May 18	2011 Calling June 2	2012 Calling April 19	2012 Calling May 15	2012 Calling June 4	2013 Calling April 16	2013 Calling May 9	2013 Calling June 10	2014 Calling April 29	2014 Calling May 21	2014 Calling June 9
American Toad			Nothing Heard	3	Nothing Heard		Nothing Heard			Nothing Heard	Nothing Heard	
Northern Spring Peeper		3				1 (1)						
Tetraploid Gray Treefrog												1 (1)
Western Chorus Frog												
Northern Leopard Frog												
Pickerel Frog												
Green Frog												
Mink Frog												
Bullfrog												
Wood Frog	1 (1)											
Beaufort Wind Scale	1	2	2	1	0	1	1			3	1	0
%Cloud Cover	10	100	0	100	0	100	80			5	0	90
Air temp. (°C)	14	14	13	11	20	15	6			7.5	20	18
Water temp. (°C)	12	N/A	10	N/A	N/A	N/A	N/A			5.5	N/A	N/A
Water pH	N/A	N/A	8	N/A	N/A	N/A	N/A			7.6	N/A	N/A
Precipitation?	None	Hard Rain	None	None	None	None	None			None	None	None

Notes:
2011
Apr 27 - Spring peepers at 90°
2012
May 15 - American toad heard beyond point count
Jun 4 - gray treefrog and American toad heard beyond point count
2013
Apr 16 - SPPE calling beyond 100m to north and west, killdeer, Canada goose and American woodcock calling
2014
Apr 29 - rain earlier in day, a couple SPPE heard behind surveyors
May 21 - no standing water present
June 9 - no standing water present

LEGEND	
X individual seen, but not calling	
# (_) call intensity and estimated number of individuals	
Call Level Codes	
1 Calls can be counted; not simultaneous	
2 Some simultaneous calls; yet distinguishable	
3 Calls not distinguishable individually; overlapping	
NA: (Not Applicable) denotes lack of water or not recorded	

Beaufort Wind Scale #	Description
0	Calm; smoke rises vertically
1	Light air movement; smoke drifts
2	Slight Breeze; felt on face, leaves rustle
3	Gentle breeze; leaves and small twigs in constant
4*	Moderate breeze; small branches are moving,
5*	Fresh breeze; small trees in leaf begin to sway,
6*	Strong breeze, large branches in motion
	Unacceptable wind strengths for amphibian surveys

Subject: HCBP - RAAP - Above limit on "HC-A(14)"
From: "Weber, Nicole" <Nicole.Weber@aecom.com>
Date: 11/3/2014 5:06 PM
To: "John Palmer (jpalmer@grandriver.ca)" <jpalmer@grandriver.ca>, "Adele.Labbe@guelph.ca" <Adele.Labbe@guelph.ca>, "Andrew Schiedel (aschiedel@nrsi.on.ca)" <aschiedel@nrsi.on.ca>

Hi Folks.

Our first RAAP notice of the year and it is on a day where air temperatures were below 10C. I had several exceedance notices Sunday and today. A staff member went out this morning to check the equipment and creek for any signs of damage, tampering or dumping. Luckily, we had a duplicate HOBO sensor in the stream near the site. I suspect the temperature sensor is failing . I will let you know when I have more information but I thought I would prep everyone for a call tomorrow afternoon.

John and Adele, I couldn't remember who the second contact was from GRCA and the City at this time. Please forward to those folks.

Cheers.
Nicole

-----Original Message-----
From: HOBOlink Alarm [mailto:hobolink-no-reply@hobolink.com]
Sent: Sunday, November 02, 2014 10:32 AM
To: Weber, Nicole; erin.jones@aecom.com
Subject: Above limit on "HC-A(14)"

Above limit alarm tripped on sensor S/N: 9816410-1 (Notes: N/A) Temperature = 24.07 °C

Please visit https://www.hobolink.com/users/1371/devices/1972/alarms to view this alarm.

Subject: RE: HCBP - RAAP - Above limit on "HC-A(14)"
From: "Weber, Nicole" <Nicole.Weber@aecom.com>
Date: 11/14/2014 3:11 PM
To: "Adele.Labbe@guelph.ca" <Adele.Labbe@guelph.ca>, "jpalmer@grandriver.ca" <jpalmer@grandriver.ca>, "aschiedel@nrsi.on.ca" <aschiedel@nrsi.on.ca>

Sorry for the delay in responding.

Yes, it was an equipment malfunction. Fortunately, we had another, redundant temperature monitor at the location for the whole season and have not lost any data.

Regards.

Nicole S. Weber, M.Sc., PhD, P.Eng.
Senior Project Manager, Water Resources, Water
D 1.519.650.8699 C 1.519.501.1404 Cisco 3208699
Nicole.Weber@aecom.com

AECOM
290-50 Sportsworld Crossing Road
Kitchener, ON N2P 0A4
Canada
T 1.519.650.5313 F 1.519.650.3424
www.aecom.com

Twitter I Facebook I LinkedIn I Google+

-----Original Message-----
From: Adele.Labbe@guelph.ca [mailto:Adele.Labbe@guelph.ca]
Sent: Thursday, November 13, 2014 3:53 PM
To: jpalmer@grandriver.ca; Weber, Nicole; aschiedel@nrsi.on.ca
Subject: RE: HCBP - RAAP - Above limit on "HC-A(14)"

Hi All,

Sorry for the delay in responding. Can you let me know if it was just an equipment malfunction?

Thank you,

Adèle Labbé | Environmental Planner
T (519) 822-1260 x 2563
E adele.labbe@guelph.ca

-----Original Message-----
From: John Palmer [mailto:jpalmer@grandriver.ca]
Sent: November 4, 2014 11:34 AM
To: Weber, Nicole; Adele Labbe; Andrew Schiedel (aschiedel@nrsi.on.ca)
Subject: RE: HCBP - RAAP - Above limit on "HC-A(14)"

Hi Nicole,

I may not be available for a call tomorrow but will try to find a new GRCA appointee to replace Nigel.
I suppose that applies to me while away for the next 15 weeks.

Best regards,
John

-----Original Message-----
From: Weber, Nicole [mailto:Nicole.Weber@aecom.com]
Sent: November-03-14 5:06 PM
To: John Palmer; Adele.Labbe@guelph.ca; Andrew Schiedel (aschiedel@nrsi.on.ca)
Subject: HCBP - RAAP - Above limit on "HC-A(14)"

Hi Folks.

Our first RAAP notice of the year and it is on a day where air temperatures were below 10C. I had several exceedance notices Sunday and today. A staff member went out this morning to check the equipment and creek for any signs of damage, tampering or dumping. Luckily, we had a duplicate HOBO sensor in the stream near the site. I suspect the temperature sensor is failing . I will let you know when I have more information but I thought I would prep everyone for a call tomorrow afternoon.

John and Adele, I couldn't remember who the second contact was from GRCA and the City at this time. Please forward to those folks.

Cheers.
Nicole

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Sent: Sunday, November 02, 2014 10:32 AM
To: Weber, Nicole; erin.jones@aecom.com
Subject: Above limit on "HC-A(14)"

Above limit alarm tripped on sensor S/N: 9816410-1 (Notes: N/A) Temperature = 24.07 °C

Please visit https://www.hobolink.com/users/1371/devices/1972/alarms to view this alarm.

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Subject: Re: HCBP Phase 2 - SWM Pond 4
From: Tara Brenton <tbrenton@nrsi.on.ca>
Date: 11/19/2014 9:48 AM
To: Tony Zammit <tzammit@grandriver.ca>
CC: Crystal Allan <callan@grandriver.ca>, "Weber, Nicole" <Nicole.Weber@aecom.com>, Steve Burgin <sburgin@nrsi.on.ca>

Hi Tony,

The RAAP team has discussed planting options relatively extensively. NRSI had originally prepared restoration plans that included plant material within the 'wetland' zones/shallow-water areas of the pond so that they could be covered in plant material and provide additional shading. The plans included a mix of shrub species that are more tolerant of standing water throughout various times of the year.

The water levels in the pond are higher than designed for, and as such, water levels are too deep in most of the pond to allow for any robust or emergent vegetation. There is a fringe of cattails growing around the edge where water levels are reasonable. In an attempt to establish vegetation within the open water area, the landscaper utilized duckweed and water lily; however, these species have migrated to the fringe areas as they were not anchored (water too deep to anchor lily), and have also been heavily browsed by the resident geese and ducks.

Some background (Nicole, feel free to provide input) - in 2012 the RAAP team made a decision to raise the pond weir in an attempt to reduce the flows from the pond to Tributary A between rain events. AECOM recommended that the weir be returned again to its design elevation to allow the pond water elevation and vegetation to establish in the design state. It's my understanding that the heightened weir was never removed; however, AECOM is undertaking annual temperature monitoring to get a better idea of impact before making a permanent change to the structure.

In the design state, there may be opportunities for the existing vegetation to spread into the shallow-water zones. The RAAP team also discussed the option of floating vegetated islands, so NRSI undertook a review of available research on actual cooling impact these floating islands can have. Based on our review, we found that the floating islands are effective at improving water quality (increased oxygen and filtering); however, there was little to no change in water temperatures in ponds where they had been implemented.

We have implemented trees and shrubs around the pond edge and along the cooling trench edge in hopes that they will provide some shading; however, I have noted to the RAAP team, that vegetation cover is only 1 mitigation option for cooling the water that is outletting to Tributary A. Vegetation can take 15-20 years (for trees) to provide a reasonable amount of shading. We can recommend additional plantings; however, I think there are still other options that should be discussed amongst the RAAP team.

With all of that said, I would be more than happy to meet with you on-site in the spring to take a look at the existing vegetation cover and discuss further options.

Thanks,

On 11/18/2014 1:33 PM, Tony Zammit wrote:

Hi Tara,

Are the pond depths suitable for narrow-leaved or robust emergents? Have you considered floating mats of wetland vegetation to create more shading? I'd be happy to meet with you on site next spring to assess the situation more closely and to come up with some possible solutions. Just let me know.

Best,
Tony

From: Crystal Allan
Sent: November-17-14 10:43 PM
To: Tara Brenton
Cc: Tony Zammit
Subject: RE: HCBP Phase 2 - SWM Pond 4

Hi Tara,
I don't know if John had an opportunity to touch base with the group again before leaving for his travels, however Tony Zammit will be GRCA's Natural Heritage contact for future communications. Tony can be reached at tzammit@grandriver.ca or 519-621-2763 ext. 2246.

Thanks,
Crystal

From: Tara Brenton [mailto:tbrenton@nrsi.on.ca]
Sent: November-17-14 9:13 AM
To: John Palmer
Cc: Grant.Ferguson@guelph.ca; Adele Labbe; Weber, Nicole; Crystal Allan
Subject: Re: HCBP Phase 2 - SWM Pond 4

Hi John,

Sorry for the delayed response. I don't have a great photo to represent the 'wetland' cell and given the snow flying right now, won't likely be able to get one until the next growing season. The vegetation planted within the wetland zone was comprised of floating species (i.e. water lily) as the water levels in that zone were predicted to be higher than would allow for anchored planting. As has occurred within the open water area in the pond, vegetation has migrated to the edges due to wave action.

Aside from potentially implementing additional plantings along the cooling trench, do you have any other recommendations?

On 11/4/2014 11:47 AM, John Palmer wrote:

Hi Tara,

Thanks for the report on HCBP SWM Pond 4 vegetation.

I notice healthy fringe vegetation in the photographs. Do you also have a photograph of vegetation in the wetland cell, i.e. in the open area between the forebay and the deep water of the main cell? This area was also to be planted to reduce the overall area of unshaded surface water.

I think that in the past we have advised planting vines to cover the cooling trench. If we have another summer like 2012 the sparse vegetation that has naturally established itself to date would not prevent the rocks and water at the surface of the trench from being over heated.

Best regards,
John

cid:ima

John Palmer, P.Eng., Water Resources Engineer
Grand River Conservation Authority
400 Clyde Road, PO Box 729, Cambridge, Ontario N1R 5W6
Tel: 519-621-2763 x2289 | Fax: 519-621-4945 | www.grandriver.ca
Toll Free 1 (866) 900-4722

From: Tara Brenton [mailto:tbrenton@nrsi.on.ca]
Sent: November-03-14 1:40 PM
To: Grant.Ferguson@guelph.ca; Adele Labbe; John Palmer; Weber, Nicole
Cc: Andrew Schiedel
Subject: HCBP Phase 2 - SWM Pond 4

Good afternoon,

To close the loop, I thought I would circulate my 2 year plant warranty inspection summary for the additional plantings that were installed within and around the Hanlon SWM Pond 4. ACORUS restoration has been contacted and they will be removing tree stakes and ties so trees aren't girdled over-time and they will also be removing any of the dead tree material so that it doesn't fall onto the adjacent trail.

I will send along the inspection maps in a separate email as they are larger in size. Feel free to contact me if you have any questions.

--

NATURAL RESOURCE SOLUTIONS INC.
Aquatic, Terrestrial and Wetland Biologists

Memo

Project No. 1041

To: **Paul Husson (Husson Ltd.), Bill Luffman (Cooper Construction)**

CC: **Grant Ferguson, Adèle Labbé (City of Guelph), John Palmer (GRCA), Andrew Schiedel (NRSI), Nicole Weber (AECOM)**

From: **Tara Brenton (NRSI)**

Date: **October 22, 2014**

Re: **HCBP Phase 2**
2 Year Warranty Inspection Summary for SWM Pond 4 Enhancement Plantings

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In response to temperature exceedances identified through AECOM's annual stream temperature monitoring program, additional plantings were recommended within and around SWM Pond 4 by the Rapid Assessment & Action Protocol (RAAP) group as a potential cooling/shading mitigation measure. The enhancement plantings were installed by ACORUS Restoration in October 2012 within the deep and shallow water areas, as well as along the shoreline and floodline fringe cooling trench.

Summary

As per the Planting Typicals and Standard Notes, a 2 year warranty inspection of the plant material was conducted by Tara Brenton (NRSI) on October 2, 2014. During the inspection it was noted that a majority of the tree and shrub plantings installed by ACORUS Restoration are in good growing condition, with only a few individuals that are dead, or are showing signs of decline. Table 1 provides a summary of the total number of trees and shrubs that were identified as live, dead or declining as part of this contract. The attached field map also identifies the location of dead or declining tree species.

Table 1. Summary of Tree and Shrub Health

Plant Material	Total Required	Alive	Dead	Declining
Shrubs	201	201	0	0
Trees	146	130	7	9
Total	**347**	**331**	**7**	**9**

The trees and shrubs installed as part of this contract were treated with Arborguard, and as a result, there was no evidence of deer or rodent browse.

Little to no aquatic vegetation was noted to be growing within the deep water zones; however, all aquatic vegetation species specified for planting within this zone were observed within the shoreline fringe area. The following species were observed scattered along the pond edge, with floating leaved pondweed, broad leaved arrowhead and sweet flag being the most dominant:

- Sweet-scented white water-lily (*Nymphaea odorata*),
- Little duckweed (*Lemna minor*),
- Giant bur-reed (*Sparganiu eurycarpum*),
- Softem bulrush (*Scirpus validus*),
- Sweet flag (*Acorus americana*),
- Broad leaved arrowhead (*Saggitaria latifolia*), and,
- Floating leaved pondweed (*Potamogeton natans*)

The deep water zone is large in size and often has relatively choppy water when there are moderate to strong winds. This is resulting in the vegetation being pushed to the pond edge in amongst the existing cattails. Canada geese (*Branta canadensis*) are also residing in the pond and frequently feed within the deep water zone, which is also likely leading to a lack of vegetation establishment in this area.

The vine species planted and the naturally regenerating vegetation species, are slowly establishing themselves along the cooling trench. Although not associated with the restoration enhancement plantings, it was noted that a few small to medium caliper trees along the new woodland edge (as a result of cooling trench installation) have fallen over the cooling trench and are providing limited shade to the rocks beneath. It is recommended that follow-up inspections be conducted along the cooling trench once the stormwater management pond is functioning to ensure that the trees are not impeding on flows.

Overall, vegetation installed as part of this contract is performing well; however, it is unlikely to contribute to significant shading of the deep water pond due to issues noted above (choppy water conditions, presence of Canada geese and scale of deep water area). Over-time, the trees, shrubs and aquatic species installed within the shoreline and floodline fringe will mature and provide shade to the shallow water areas.

Recommendations

Tree stakes and ties that were installed as part of this contract are to be removed. It was also noted during the site visit that the tree stakes and ties from the previous contract by Valterra Landscaping still need to be removed from trees around SWM Pond 4, as well as throughout the entire site to ensure that trees are not girdled over-time.

There were very few dead or declining tree species identified for this contract, therefore, it is felt that replacement of the stock is not warranted. It is recommended that the dead trees be removed or pushed over when contractors are on-site removing the tree stakes and ties. This will ensure that the dead plant material does not fall onto the adjacent multi-use trail.

A follow-up inspection is recommended to ensure that all tree stakes and ties have been removed for both contracts.

I trust the above information is adequate. Should you have any questions or comments, please do not hesitate to contact the undersigned.

Sincerely,
Natural Resource Solutions Inc.

Tara M. Brenton, B.Sc., Certified Arborist
Terrestrial and Wetland Biologist


Photo 1: Vegetation growth along edge of SWM Pond 4 – View N


Photo 2: Vegetation growth along edge of SWM Pond 4 – View NE


Photo 3: Vegetation growth along edge of SWM Pond 4 – View NW


Photo 4: Fallen trees and vegetation growth along cooling trench – View W
**Note that herbaceous vegetation was observed to be more prominent during the growing season – see photos below*


Photo 5: Vegetation growth observed along cooling trench during growing season (July 2014)


Photo 6: Vegetation growth observed along cooling trench during growing season (July 2014)