19 September 2023 Reference No. 22572560-002-L-Rev1

Laura Beckett, Municipal Planner, Deputy Approving Officer
District of Highlands
1980 Millstream Road
Victoria, BC V9B 6H1

RESULTS OF 2022 GROUNDWATER LEVEL MONITORING PROGRAM, DISTRICT OF HIGHLANDS, BC

Dear Ms. Beckett,

As requested by the District of Highlands (the District), WSP Canada Inc., (WSP) conducted a groundwater level monitoring program in the District of Highlands, BC (the Highlands) for 2022. WSP conducted the groundwater level monitoring program in accordance with our proposal titled "Work Plan and Cost Estimate for 2022 Groundwater Level Monitoring Program, District of Highlands, BC" (WSP Reference No. CX22572560-001-P-Rev1) and dated 10 February 2023.

Our letter should be interpreted and used in accordance with the limitations and considerations set out in WSP's *Study Limitations*, provided at the end of this letter.

1.0 BACKGROUND AND OBJECTIVE

The Highlands is one of the 13-member municipalities of the Capital Regional District (CRD), encompassing approximately 37 square km and located northwest of Victoria, BC. The majority of the residential population of 2,482 obtains potable water from private, individual water wells (Statistics Canada, 2023). Commercial groundwater use is limited to the southern portion of the Highlands. The Hanington Estates subdivision, located along the southern portion of the Highlands, obtains water from a water system ("Hanington Estates Water System") that is supplied by two communal supply wells. Irrigation water for the Bear Mountain Golf Course (Bear Mountain) is sourced from groundwater wells located within the Highlands. Some businesses within the Millstream Industrial Park, located in the Highlands and Langford, had historically used groundwater for commercial purposes; the CRD municipal Regional Water Supply System was extended into this area and may represent the primary water supply for businesses in the industrial park.

As per the BC *Water Sustainability Act* (WSA), groundwater use for purposes other than domestic supply must apply for and obtain a groundwater license. Groundwater licensing, which is administered by the Ministry of Forests, establishes rights to groundwater and specifies how much water one can legally use. As of June 2023, one groundwater licence (License No. 501806) was documented on the provincial Water Rights Databases for the Highlands (Government of British Columbia, 2023). This Conditional Water Licence was issued in the southern portion of the Highlands for irrigation and land improvements at the Bear Mountain Golf Course; further details are provided in Section 3.4.

1.1 Aquifer Description

Groundwater supplies within the Highlands are derived primarily from drilled wells completed in the Wark-Colquitz Aquifer. This bedrock aquifer is identified as Aquifer No. 680 by the BC Ministry of Environment and Climate Change Strategy (ENV) and is categorized as class IB under the BC Aquifer Classification System, indicating high demand relative to a moderate aquifer productivity and moderate vulnerability of the aquifer to contamination from surface sources. Sewage servicing within the Highlands is primarily by individual septic systems.

1.2 Groundwater Monitoring and Mapping Programs

On behalf of the District, WSP (formerly Golder Associates Ltd.; work conducted prior to 2021 herein referred to as Golder) initiated a groundwater level monitoring program in the Highlands in 2009 in support of the District's Groundwater Protection Study (Golder 2009). The water level information from the monitoring program was used to assess seasonal groundwater level variations and, in 2012, to refine a numerical groundwater model that Golder developed, calibrated and used to conduct water balance analyses. At the completion of the Groundwater Protection Study, Golder recommended that the District continue to monitor groundwater conditions at select locations in the Highlands to assess long-term trends. If trends were to be observed, the results would provide the basis for guiding implementation of management strategies including conservation and groundwater protection measures, and public education efforts. The monitoring well locations were selected in discussion with the District's Groundwater Task Force to support ongoing monitoring at locations across the Highlands in areas of groundwater recharge and discharge, in a cost-effective manner; the six locations selected are listed in Table 1, and discussed below. Further details are provided in Golder's report titled "Phase 3: Groundwater Protection Study District of Highlands, District of Highlands Victoria, BC" (Report No. 0714140014-501-R-Rev2-3000) and dated 18 December 2012.

The groundwater monitoring program has been continued since 2009 to the present. As of the end of 2022, pressure transducers were deployed in five monitoring wells located across the Highlands to collect continuous water level data at strategic locations, and one additional pressure transducer (a "barologger") was deployed to monitor changes in barometric (i.e., atmospheric) pressure. The locations of monitoring wells DOH-01, DOH-03, DOH-04B, DOH-07B and DOH-09A are presented on attached Figure 1. Monitoring Well DOH-02A, which had been included in the monitoring program since 2009, was removed from the monitoring program in February 2018 at the property owner's request. The location of DOH-02A is also shown on Figure 1. A summary of the total depths of the Highlands monitoring wells and the Well Tag Numbers (WTNs) that have been assigned by the BC Ministry of Environment and Climate Change Strategy (BC ENV) is provided in Table 1, below.

Table 1: Summary of Well Tag Numbers for District of Highlands Monitoring Wells

District of Highlands Monitoring Well	Total Depth m bgs (ft bgs)[a]	Well Tag Number[b]
DOH-01	152 (499)	79405
DOH-02A	56 (185)	85719
DOH-03	91 (300)	79581
DOH-04B	53 (175)	48812
DOH-07B	152 (500)	69716
DOH-09A	46 (150)	79583

Notes: a. m bgs = metres below ground surface; ft bgs = feet below ground surface
b. Well Tag Number assigned by the Province and reported on Groundwater Wells and Aquifers (WELLS) database

Monitoring wells DOH-02A, DOH-07B and DOH-09A are unused wells that are not equipped with pumps (i.e., are not in operation). The water levels in these wells are generally considered to be representative of static groundwater levels in the aquifer in the vicinity of the wells. However, groundwater flow within a bedrock aquifer is variable and through discrete fractures. Therefore, water levels at a given location can be influenced by pumping of wells in the area.

DOH-03 and DOH-04B are equipped with pumps and operated as supply wells for non-potable uses (i.e., not for drinking water). Although DOH-01 is an unused well, the water level in this well is influenced by pumping in an adjacent well. Water levels in DOH-01, DOH-03 and DOH-4B are not considered representative of the water levels in the surrounding aquifer during periods of pumping, but the high-water levels are interpreted to represent static (i.e., non-pumping) periods and can provide a basis to assess groundwater conditions in the areas of these wells.

The CRD is currently pursuing a Certificate of Compliance (CoC) from BC ENV for the Millstream Meadows site located in the southern portion of the Highlands at 1965 Millstream Road and adjacent to the District's office property at 1980 Millstream Road. This has involved drilling and installation of monitoring wells to assess groundwater conditions; one of the monitoring wells was drilled at the District's office property. In 2021, the CRD provided the District with water level data that were collected in 2020 from multi-level monitoring well MW19-96 that was installed approximately 60 m northeast from the District office.

As part of the 2021 annual groundwater monitoring program, WSP conducted a review of additional mapping work that had been done by GW Solutions Inc. (GW Solutions). Based on the results of that review, WSP provided recommendations for potential strategic refinements to the Highlands monitoring program, including consideration of additional monitoring locations. This could include redeployment of the transducer at DOH-02A and engaging with other stakeholders such as the Province and CRD, the Hanington Estates Water System and owners of private wells on residential properties. Further details are provided in the 2021 annual monitoring report (WSP, 2022).

1.3 Objective

The objective of the 2022 groundwater level monitoring program was to continue to implement the Highlands groundwater monitoring program and to compile and analyse data from the Highlands and stakeholder monitoring programs to assess regional groundwater conditions and potential long-term trends.

2.0 METHODS

2.1 Groundwater Level Monitoring

The transducers that are installed in the Highlands monitoring wells, including the barologger that is deployed at monitoring location DOH-01, are programmed to collect data every twelve hours. Under the current program, WSP downloaded pressure transducer data and collected a manual depth-to-water measurement at each of the active monitoring locations in the Highlands on 8 September 2022 and 19 May 2023. WSP also downloaded transducer data and collected water level measurements at the monitoring wells earlier in the year on 9 March 2022 as part of the 2021 monitoring program.

2.2 Data Compilation and Analysis

In addition to the District's monitoring program, WSP also obtained data from other stakeholder monitoring programs in the Highlands including the following:

- University of Victoria (UVic) School-Based Weather Station Network: data available on-line for UVic weather stations, located at various areas of the Highlands, as described below
- BC ENV Provincial Groundwater Observation Well Network (PGOWN): water level data available on-line from BC ENV Well No. 372 (WTN 83045), located in the western portion of the Highlands
- Hanington Estates Water System: flow data available from Island Flow Control Water Solutions Ltd. (IFCWS) for the Hanington Estates Water System, in the southern portion of the Highlands

The locations of the monitoring wells and weather stations from the various stakeholder monitoring programs are presented on attached Figure 1.

WSP compiled the raw pressure data from the Highlands monitoring wells and corrected the data for variations in barometric pressure, as recorded by the barologger, to calculate depth to groundwater levels for each Highlands monitoring well. WSP also checked the barometrically corrected transducer data with the manual depth to water measurements that were collected during each monitoring event. As discussed in Section 1.2, water levels in the Highlands monitoring wells are influenced either directly by periodic pumping (i.e., DOH-03 and DOH-4B) or, given the bedrock setting, pumping by adjacent wells, particularly at DOH-01. The water level data are estimated to range from plus or minus 0.01 to 0.02 m relative to manual measurements for DOH-07B and DOH-09A, to up to approximately 0.08 to 0.20 m for DOH-03 and DOH-01, respectively. This reported variability for DOH-03 and DOH-01 reflects the influence of pumping at the times of data collection, as described above; water level monitoring that was conducted close to the 12:00 PM reading for DOH-01 in September 2020 and for DOH-03 in May 2023 indicated that the transducer readings were within 0.03 and 0.05 m of the corresponding manual measurements, respectively. This precision is considered appropriate for a regional water monitoring program that assesses seasonal patterns and long-term trends.

WSP also compiled water level data available from BC ENV Well No. 372 and precipitation data from the UVic weather stations that have been analysed during previous years. Limited precipitation data were available for some of the weather stations for periods that extended from a few days to several months; however, the data are considered sufficient for assessing general precipitation patterns. Similar to recent annual monitoring programs, WSP compiled precipitation data from weather stations with available data as follows:

- **Northern Highlands:** Water level data for DOH-07B were compared to precipitation data for the Cal Revelle Nature Sanctuary Weather Station, located approximately 20 m north from DOH-7B and at an elevation of 221 metres above sea level (masl).
- **Southern Highlands:** Water level data for DOH-01 and DOH-03 had been compared to precipitation data for the District of Highlands Office Weather Station, adjacent to DOH-03, for the period of 1 January 2012 to 31 January 2016. For the period 1 February 2016 to 31 December 2021, precipitation data from the

Millstream Elementary School Weather Station were primarily used[1]. Precipitation data for the Millstream Elementary School station were incomplete for 2022. Therefore, for the period 1 January to 31 December 2022, precipitation data from the Lakewood Elementary School Station were used for the analysis. The Millstream Elementary School and Lakewood Elementary School stations are located approximately 2.1 km southeast and 1.8 km south of the District of Highlands Office station, respectively (Figure 1). The elevations at the Millstream Elementary School station (80 masl) and Lakewood Elementary School Station (88 masl) are lower than the District of Highlands Office (104 masl).

- **Western Highlands:** For the period 1 January 2012 to 28 February 2017, water level data for DOH-04B and BC ENV Well No. 372 were compared to precipitation data from the West Highlands District Firehall weather station, located approximately 200 m northwest from DOH-04B and at an elevation of 154 masl. Beginning in March 2017, data for the West Highlands District Firehall Station were only available for certain periods until 2021 . Therefore, precipitation data from the Cal Revelle Nature Sanctuary Weather Station, located approximately 3.5 km northeast of the West Highlands District Firehall station (elevation of 221 masl), were compared to water level data from DOH-04B and BC ENV Well No. 372 for the period 1 March 2017 to 31 December 2020, after which, data were once again consistently available for the West Highlands District Firehall station.
- **Eastern Highlands:** Water level data for DOH-09A had been compared to precipitation data for the East Highlands District Firehall weather station (elevation of 101 masl) from 1 January 2012 until 31 May 2014, after which data were not consistently available for this station until approximately 2019. Therefore, for the period 1 June 2014 to 31 December 2018, water level data from DOH-09A were compared to precipitation data from the Cal Revelle Nature Sanctuary Weather Station, located approximately 4 km northwest from DOH-09A.

Data from the Highlands and stakeholder monitoring programs were plotted, and the results analysed to assess seasonal and long-term trends. The District advised that the CRD had not monitored groundwater levels in the Millstream Meadows test well that is located on the District's office property since 2020. Therefore, data from this well were not available for review at the time of this letter report.

WSP also reviewed flow data for the Hanington Estates Water System, as provided by IFCWS.

3.0 RESULTS AND DISCUSSION

3.1 District of Highlands Monitoring Program

Detailed water level data for monitoring wells DOH-01, DOH-03, DOH-04B, DOH-07B and DOH-09A for the period from 1 January 2012 through 31 December 2022, together with daily precipitation data from nearby weather stations, are presented on Figures 2 through 6. The precipitation data are provided to illustrate the relationship between precipitation and groundwater levels. As discussed in Section 2.2, data from different weather stations were used based on completeness of the datasets available from the different UVic School-

[1] Data from Millstream Elementary School Weather Station were not available from 13 July 2019 to 19 September 2019. Therefore, data from the District of Highlands Office was used for this time period.

Based Weather Stations to assess precipitation in the Highlands. Although it is expected that there is some variability in precipitation patterns across the Highlands, the precipitation data presented on Figures 2 through 6 are considered suitable for the purposes of assessing general groundwater level patterns and their relationship to precipitation. Furthermore, groundwater recharge into the bedrock aquifer is interpreted to be in part controlled by the properties of the bedrock and not necessarily the intensity of specific precipitation events. Therefore, it is anticipated that minor changes in precipitation in different areas of the Highlands would not necessarily be reflected in significant variations in regional groundwater level conditions.

In 2022 the water levels that were recorded in the majority of the Highlands monitoring wells were generally consistent with seasonal precipitation patterns that were observed in previous years. Groundwater elevations were highest in the wet winter months of December to April, declining to a seasonal low during the dry summer period from May to September before increasing in response to precipitation from late October to December. Seasonal responses in 2022 ranged from approximately 5.5 m in DOH-04B to approximately 3.6 m in DOH-03. As discussed above, the water level in DOH-01 is inferred to be influenced by pumping of an adjacent well, resulting in isolated periods of drawdown; the seasonal response of the static water level in DOH-01 is estimated to be in the range of 4.0 to 4.5 m.

In 2022, the precipitation recorded from August to mid-October was less than what had been observed in previous monitoring years and temperatures were particularly high in August to October compared to previous years. As a result, the precipitation recorded during the fall and early winter of 2022 was less than what had been observed in previous monitoring years. As an example, the total precipitation of 1.7 mm that was reported for the Cal Revelle Nature Sanctuary weather station from 1 August through 20 October 2022 was less than typical values recorded at this station; over the past 10 years, precipitation during the same period has ranged from 73 mm in 2018 to 259 mm in 2020. Although water levels in the Highlands monitoring wells during the dry season of 2022 were relatively low compared to previous monitoring years, consistent with less recharge from precipitation, the water levels in the monitoring wells recharged during the wet season in 2022 and were relatively consistent with previous monitoring years. The total precipitation of 362.3 mm that was reported for the Cal Revelle Nature Sanctuary weather station from September through December 2022 was similar to previous values for this station that ranged from 370.5 mm in 2019 to 972.1 mm in 2021.

As discussed in Section 1.2, the water level in monitoring well DOH-01 is influenced by pumping in one or more nearby wells. The inferred static groundwater level of approximately 11.2 metres below the top of the casing (mbtoc) that was measured in DOH-01 late in the summer of 2022 was similar to values reported for most of the previous monitoring years (Figure 2). The lowest isolated (i.e., pumping induced) water level of approximately 17.5 mbtoc that was recorded for DOH-01 during the summer of 2022 was higher than those that were below 25.9 mbtoc during the summers of 2012, 2016 and 2017; the level of 25.9 mbtoc was the level at which the pressure transducer was set, and the water level is inferred to have declined below this level during isolated pumping events. The patterns observed in the summers of 2018 to 2022 could potentially reflect less sustained pumping from nearby wells. The seasonal high water level of approximately 9.4 mbtoc that was recorded at DOH-01 late in December of 2022 was generally within the low range of those in recent monitoring years following a seasonal high of approximately 8.6 mbtoc that was observed in 2012 (Figure 2). Continued monitoring will provide the data required to assess if this is a long term trend or reflects variability between years.

The seasonal low water level of approximately 7.6 mbtoc that was measured in DOH-03 in October 2022 was low relative to previous monitoring years, with the exception of the summer to early fall of 2013 to 2016, when seasonal lows ranging from approximately 7.6 to 8.1 mbtoc were recorded (Figure 3). The seasonal high water level of approximately 4.3 mbtoc that was observed in December 2022 was also relatively lower than what had been observed in previous monitoring years, as the isolated water levels above 4 mbtoc are inferred to reflect short duration responses to precipitation events; however, for some monitoring years, seasonal high water levels in DOH-03 have been observed later in the wet season (i.e., early months of the year).

The seasonal low water levels observed in 2022 in DOH-04B and DOH-09A were similar to those observed in 2021 and relatively lower than the levels in 2018 to 2020, but similar to previous monitoring years (Figures 4 and 6). The seasonal low water levels in DOH-04B and DOH-09A were as low as 9.5 and 5.2 mbtoc, respectively, in 2012, compared to the 2022 the seasonal low water levels were 7.6 mbtoc in DOH-04B and 4.6 mbtoc in DOH-09A. The seasonal high water levels in these wells have generally been consistent over the duration of the Highlands monitoring program. The seasonal high of 2.1 mbtoc in DOH-04B in December 2022 is in the range of approximately 1.9 to 2.3 mbtoc that has been observed during previous years. The seasonal high in DOH-09A increased slightly between 2012 and 2021 from approximately 0.1 m below to 0.5 m above the former top of the casing of DOH-09A, prior to the casing for this well being extended by approximately 1.24 m in October 2011. The seasonal high in DOH-09A in 2022 was within this range, at a height of 0.1 above the former top of casing.

As presented on Figure 5, the seasonal low water level of 11.0 mbtoc that was recorded in DOH-07B in mid October 2022 was similar to values that had previously ranged from 9.8 mbtoc in 2013 to 11.7 mbtoc in 2016; the isolated period of drawdown to 12.1 mbtoc observed on 30 August 2016 corresponded with a period of extended pumping in an adjacent well on the property. Although the seasonal high values for DOH-07B exhibited an apparent declining trend from 5.5 mbtoc in 2012 to 5.9 in 2018, a seasonal high value of 5.6 mbtoc was observed in January 2022, reflecting seasonal recharge that was consistent with recent years. As reported in previous annual reports, the lowest water level recorded in DOH-07B is approximately 140 m higher than the reported depth of the well (152.4 m below ground surface; bgs).

3.2 BC Ministry of Environment and Climate Change Strategy Observation Well

Water level data for BC ENV Well No. 372 are plotted with precipitation data from the West Highlands District Firehall and Cal Revelle Nature Sanctuary weather stations on Figure 7. The water level pattern observed in BC ENV Well No. 372 continued to be generally consistent with those observed in the Highlands monitoring wells, declining through the spring and summer months and then increasing in response to seasonal precipitation in the fall and winter.

The seasonal low water level of 61.4 mbtoc that was reported for BC ENV Well No. 372 in early November 2022 was consistent with the low water levels that ranged from 61.4 mbtoc in October of 2021 and 61.8 in mid October in 2020. As presented on Figure 7, periods of consistent low water levels that were reported in the dry seasons of 2015, 2016 and 2017 are inferred to reflect periods when the water level dropped below the pressure transducer that was deployed in the well. Therefore, the low water levels in monitoring years prior to 2018 were lower than what are plotted on Figure 7 and may have been similar to those reported for 2018 to 2022.

The water level in BC ENV Well No. 372 began increasing in late October 2022 in response to seasonal precipitation. In late 2022, the water level was as high as 45.6 mbtoc in December, within the range of what had been recorded for previous winters. It is noted that the variable water levels reported for this monitoring well during the period of the Highlands monitoring program may reflect movement of the transducer and potentially placement at different depths that may have affected the data.

3.3 Hanington Estates Water System

Water supply for the Hanington Estates Water System is sourced from two groundwater supply wells. Well 409 (Well Tag No. 85183) is operated as the primary water supply for the Hanington System and Well 500 (Well Tag No. 85184) is operated periodically as a backup supply. During the 307-day period from 25 January 2022 to 28 November 2022, the total flows from Wells 409 and 500 were reported to be 19,556 cubic metres (m^3) and 5,358 m^3, respectively, for a combined flow of 24,914 m^3. Based on these numbers, the average groundwater use for the Hanington Estates Water System during this period was estimated to be 81.15 m^3/day. This value is lower than the value of 86.32 m^3/day that was estimated for 2021; however, the average rate of daily groundwater use for 2021 was calculated for the 204-day period from 10 May 2021 to 30 November 2021 which included relatively fewer days in the winter period when daily water use is lower and would result in a lower calculated daily average.

IFCWS also provided flow monitoring data for the overall water system. Although considered to be less accurate than the flow data for the individual wells (Well 409 and Well 500), the data for the water system suggest that approximately 52% of the annual use in 2022 occurred between May and September, with the highest demand between the months of June through September. These results, which are inferred to reflect higher irrigation and other outdoor water use during the hotter, drier summer months, are consistent with values of 49% (2020) to 60% (2017) of the annual use occurring between May and September. The lower percentage of water used during May to September of 2019 and 2020 compared to previous years may be due to the increased total precipitation in the summer seasons of those years.

The population in the Hanington Estates subdivision is reported to have been 200 residents in 2022, the same value since 2017, and up from 190 residents in 2016[2]. Based on this information, the average per capita water use for the Hanington Estates water system was calculated to be approximately 406 litres per person per day (L/p/d) for the period from 25 January 2022 to 28 November 2022. The average per capita estimate for 2022 is slightly lower than the value of 432 L/p/d that was calculated for 2021; however, it was similar to the value of 406 L/p/d that was calculated for 2020. As discussed above, the average for 2020 and 2021 were calculated from water usage during a period that included a relatively greater proportion of winter months when water use is typically lower.

Water level data were not provided for Well 409 and Well 500 for 2022.

[2] Population information, as provided by the District of Highlands in file “Estd Pop_Hanington Creek Estates_2013-2022.docx”, that is based on Occupancy Permits, Stats Canada 2011, 2016, and 2021 Census data and Building Official’s observations.

3.4 Bear Mountain Monitoring Program

Similar to previous years, in 2022, continuous water level data were collected with dedicated pressure transducers that were deployed in Irrigation (i.e., pumping) Wells 405, 407 and 411, and Observation Wells 400 and 412 (WWAL, 2023). Although in previous years flow rates had been measured with digital flow meters, in 2021 the digital flow meter which measures flow and volume into Osborne Pond (the primary reservoir for the Valley Golf Course) malfunctioned and data for 2021 and 2022 were not available. Therefore, WWAL calculated the gross groundwater extraction from the irrigation wells in 2022 based on past extraction and groundwater usage volumes from previous years. With this method, WWAL estimated the total groundwater extraction from the irrigation wells to be 222,000 m^3 in 2022, with 112,500 m^3 estimated to have been pumped into the Mountain Pond and 109,500 m^3 pumped into the Osborne Pond. The estimated groundwater extraction of 222,000 m^3 is within the range of values that have been reported since flow monitoring began in 2013 and less than the value of 271,449 m^3 that was estimated for 2021. Previous annual volumes were reported to range from 196,650 m^3 in 2013 to 344,500 m^3 in 2016; however, it is noted that the values for 2021 and 2022 were estimated and may not reflect actual use.

Based on a water balance that was conducted by Colquitz Engineering Ltd. (CQZ) and estimated that approximately 74% of the groundwater that is pumped into Osborne Pond recharges the aquifer, WWAL estimated that net groundwater extraction from the irrigation wells for the Valley Golf Course to be approximately 28,500 m^3 in 2022. WSP notes that there is uncertainty regarding the recharge estimate provided by CQZ and what proportions of leakage from Osborne Pond discharge to downgradient surface water bodies (i.e., streams and wetlands) and to the deeper bedrock aquifer.

In 2022, pumping of Wells 405, 407 and 411 began on 20 July and continued until 25 October; both of these dates are relatively later in the season compared to previous years. Extraction rates for the individual wells were not reported. During this pumping period, maximum drawdown in the irrigation wells was reported to be approximately 21 m, 51 m and 85 m in Wells 405, 407 and 411, respectively; these values are within the range of those reported in previous monitoring years. WWAL reported that in the fall of 2022, the water levels in Wells 407 and 411 recovered to 100% of the pre-pumping groundwater levels by mid- to late November (i.e., within approximately a month). Full recovery of water levels in Wells 407 and 411 has ranged from approximately 10 days (2013) to 7 weeks (2018) in previous years.

WWAL also reported that in 2022 the static water levels in Observation Wells 400 and 412 did not appear to be significantly impacted by pumping of the irrigation wells. WWAL has interpreted these results to indicate that the observation wells are hydraulically separate from the lineament (i.e., fault/fracture zone) in which the irrigation wells are completed.

WWAL also noted that in June 2017 Ecoasis had submitted an application to the Province of British Columbia for an Existing Use Groundwater License for an annual diversion of 375,000 m^3 of groundwater from its three Irrigation Wells 405, 407 and 411. This application was under review by the Province at the time of WWAL's report. WWAL also identified that the Province had been in contact with Ecoasis regarding the Bear Mountain groundwater licence application and a recommendation was provided to conduct water level monitoring for Hatcher's wetland, adjacent to Millstream Creek; however, no further information was provided in WWAL's report.

As discussed in Section 1.2, Conditional Water Licence No. 501806 was issued on 23 June 2023 for industrial (lawn, fairway and garden) and land improvement purposes. The licence indicates that the maximum annual quantity of water that can be diverted is 243,180 m^3/year for industrial purposes and 36,520 m^3/year for land improvement purposes. The authorized works include the wells with Well Tag No.s 79523, 81690 and 95749 (i.e., Bear Mountain Irrigation Wells 405, 407 and 411). A copy of the Conditional Water Licence and supporting documentation, as provided on the provincial Water Rights Databases, is provided in Attachment 1 for reference.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The results from the 2022 Highlands groundwater monitoring program were generally consistent with the seasonal patterns reported for previous years. Groundwater levels were generally within the range of what has been reported for previous monitoring years. In 2022, precipitation during the late summer to fall months (August through mid-October) was less than the precipitation observed for this period in previous years monitored; however, groundwater levels were observed to recover following onset of seasonal precipitation in the fall of 2022, similar to previous years. Continued monitoring is required to provide the data required to assess if the relatively lower seasonal high water levels observed in DOH-01 and DOH-03 in recent years is a long term trend or reflects variability between years.

The results from stakeholder monitoring programs were also generally consistent with previous years. Average water use at Hanington Estates that was estimated to be approximately 81.15 m^3/day for the period January 2022 to November 2022, was within the range of values that have been reported since annual well flow data have been provided (2013). When the population of the Hanington Estates subdivision is considered, the per capita water use for the Hanington Estates water system has declined steadily from an estimated value of 473 L/p/d in 2013 to 338 L/p/d in 2019; however, values of 405.8 L/p/d (2022) to 431.6 L/p/d (2021) have been reported since that time. It is noted that the calculated average water use values vary based on the monitoring period (i.e., number of days over which the average was calculated).

During the dry season of 2022, the total volume of groundwater that was pumped from Bear Mountain Irrigation Wells 405, 407 and 411 was not measured due to a malfunction with the digital flow meter. In 2022, pumping from the three irrigation wells began on 20 July and continued until 25 October; these start and end dates were generally later than in previous years. The pumping-induced drawdown levels that were observed in the irrigation wells in 2022, at values of approximately 21 m (Well 405), 51 m (Well 407) and 85 m (Well 411), were also within the range of levels that have been reported in previous monitoring years. The water levels in Wells 407 and 411 recovered to 100% of the pre-pumping levels within a month, compared to the range of 10 days to 7 weeks that were observed in 2013 and 2018, respectively. Conditional Water Licence No. 501806 was issued on 23 June 2023, permitting Bear Mountain to divert groundwater for industrial purposes (lawn, fairway and garden; maximum annual quantity of 243,180 m^3) and land improvement purposes (maximum annual quantity of 36,520 m^3).

4.2 Recommendations

WSP recommends that the Highlands groundwater monitoring program, including review of stakeholder programs, continue in 2023 to continue to document conditions and assess groundwater levels across the Highlands.

Regarding potential refinements to the current monitoring program, WSP recommends that a pressure transducer be redeployed in DOH-02A. A survey could also be conducted to identify other potential wells that could be included in the monitoring program. To support this survey, strategic locations in the current monitoring well network should be identified. A plan should also be developed to acquire the necessary equipment (e.g., additional pressure transducers) to refine the program and to replace existing equipment on a regular schedule.

WSP also recommends that the District consider potential opportunities to collaborate with other parties to share resources and achieve similar objectives in a cost-effective manner. As outlined in the WSP (2022) 2021 annual monitoring report, potential options include the following:

- The District may be able to team with the Province to establish additional monitoring locations through a number of programs including: the PGOWN program, a network of hydrometric stations is also maintained under the Canada-British Columbia Hydrometric Program that is co-managed by the Province and the Federal Government, and the groundwater licensing process.
- The District could contact the CRD to discuss the potential to maintain one or more of the monitoring wells at the Millstream Meadows site for long term monitoring. The District could also consider options to engage with operators of other C/I properties in the southern portion of the Highlands to establish additional monitoring wells. These programs could include monitoring of both groundwater levels and groundwater quality.
- There may be an opportunity to work with the operator of the Hanington Estates Water System to include collection of continual water level monitoring data from the production wells, and potentially an observation well if present, in addition to the flow meter data that are currently collected. It is anticipated that water level monitoring may be required by the Province for groundwater licensing.
- There may also be opportunities for the District to work with community-based programs, including stewardship groups and residents who are interested in citizen science initiatives to expand monitoring network in the Highlands. These programs could include groundwater and hydrometric monitoring.
- The District could also engage with owners of wells on residential properties. The District could conduct a survey of well owners to update its database and identify residents who would be interested to volunteer use of a well on their property and to participate in a pilot water metering program. Based on the responses, the District could assess whether there are opportunities to expand the monitoring network in key areas of the Highlands.

5.0 CLOSURE

We trust the above information meets your current needs. If you have any questions or require additional information, please do not hesitate to contact the undersigned.

Yours very truly,

WSP Canada Inc.

Alanna Umphrey, AScT, PMP
Project Manager

Mark Bolton, MSc, PGeo
Senior Principal Hydrogeologist

Engineers and Geoscientists BC
Permit to Practice #1000200

AU/MB/jts

Attachments: Figure 1: Monitoring Locations
Figure 2: Depth to Groundwater Monitoring Well DOH-01 and Precipitation in Southern Highlands
Figure 3: Depth to Groundwater Monitoring Well DOH-03 and Precipitation in Southern Highlands
Figure 4: Depth to Groundwater Monitoring Well DOH-04B and Precipitation in Western Highlands
Figure 5: Depth to Groundwater Monitoring Well DOH-07B and Precipitation in Northern Highlands
Figure 6: Depth to Groundwater Monitoring Well DOH-09A and Precipitation in Eastern Highlands
Figure 7: Depth to Groundwater Monitoring Well MoE Observation Well 372 and Precipitation in Western Highlands
Attachment 1 – Conditional Groundwater Licence for Bear Mountain Golf Course

6.0 REFERENCES

Golder Associates Ltd., (Golder) 2009. Phase 2: Groundwater Protection Study District of Highlands. Golder Report No. 07-1414-0014-2000. December 2009.

Golder Associates Ltd., (Golder) 2012. Phase 3: Groundwater Protection Study District of Highlands. Golder Report No. 0714140014-501-R-Rev2-3000. December 2012.

Government of British Columbia, 2023. Water Rights Databases. available online at: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-licences-approvals/water-rights-databases. accessed July 2023.

Statistics Canada, 2023. Census Profile, 2021 Census of Population. online database: https://census.gc.ca/census-recensement/index-eng.cfm. accessed June 2023.

Western Water Associates Ltd. (WWAL), 2023. Bear Mountain 2022 Annual Groundwater Monitoring Report. WWAL File No. 16-092-01. April 2023.

WSP Golder, 2022. Results of 2021 Groundwater Level Monitoring Program, District of Highlands, BC. Reference No. 21476767-002-L-Rev0. October 2022.

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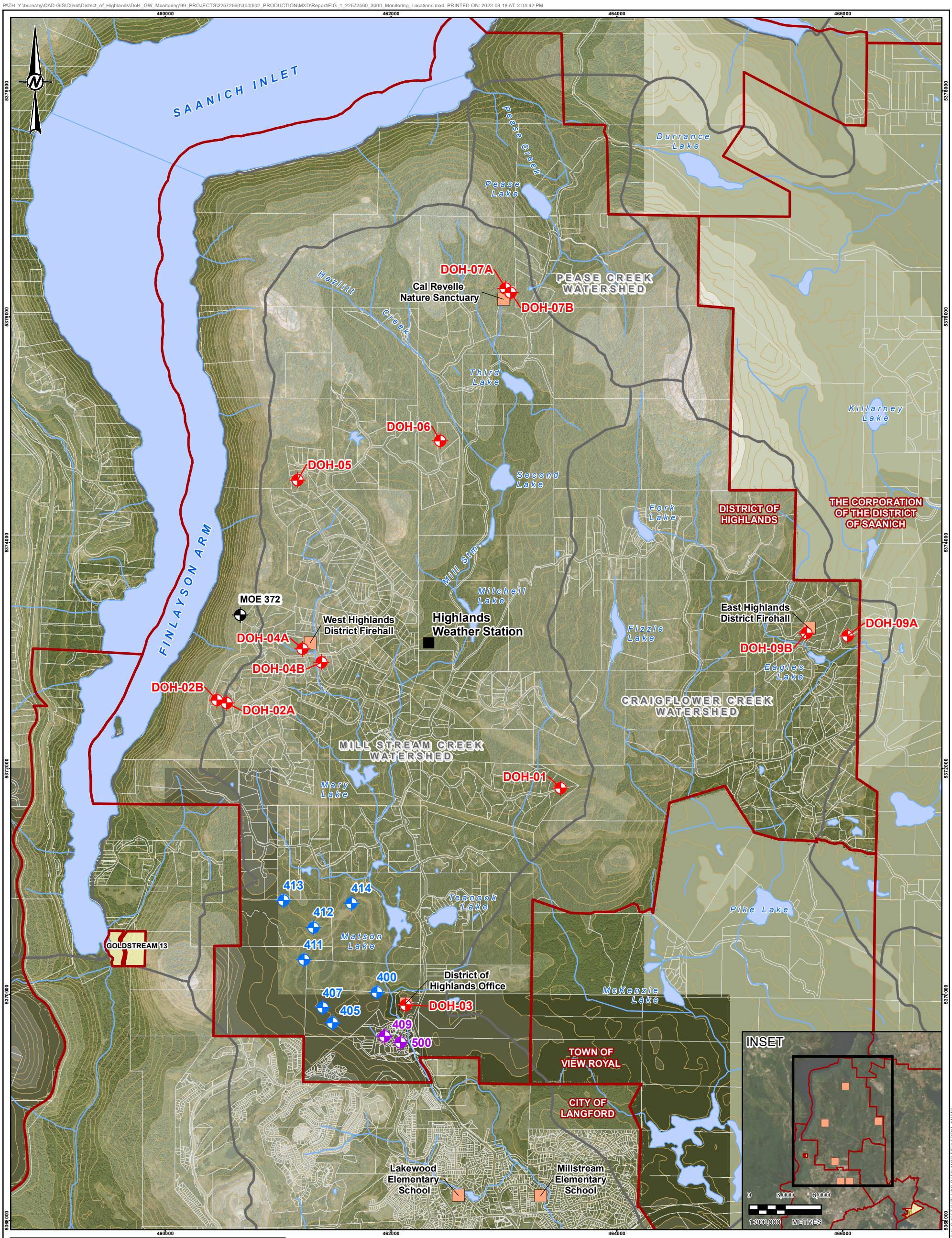

LEGEND

- District of Highlands Monitoring Well Location
- Hanington Creek Estates Well
- Bear Mountain Well
- Ministry of Environment Observation Well No. 372
- Environment Canada Weather Station
- University of Victoria Weather Station
- Contour (20m Interval)
- Watercourse
- Waterbody
- Parcel Fabric
- Major Watershed Boundary
- Municipal Boundary
- Indian Reserve

Elevation - metres above sea level (masl)

- 0 - 100
- 101 - 200
- 201 - 300
- 301 - 400
- 401 - 500

0 640 1,280
1:32,000 METRES

REFERENCES

1. DATA PROVIDED BY THE DISTRICT OF HIGHLAND AND BC ILMB.
2. WEATHER STATIONS OBTAINED FROM ENVIRONMENT CANADA AND THE UNIVERSITY OF VICTORIA SCHOOL-BASED WEATHER STATION NETWORK.
3. PARCEL FABRIC, MUNICIPAL BOUNDARY, INDIAN RESERVE, WATERBODY AND WATERCOURSE DATA CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENSE – BRITISH COLUMBIA.
4. IMAGERY COPYRIGHT © 20230214 ESRI AND ITS LICENSORS. SOURCE: MAXAR. USED UNDER LICENSE, ALL RIGHTS RESERVED..

COORDINATE SYSTEM: NAD 1983 UTM ZONE 10N

CLIENT
DISTRICT OF HIGHLANDS

PROJECT
GROUNDWATER PROTECTION STUDY
HIGHLANDS, B.C.

TITLE
MONITORING LOCATIONS

CONSULTANT
wsp

YYYY-MM-DD	2023-09-18
DESIGNED	AU
PREPARED	LH
REVIEWED	AU
APPROVED	MAB

PROJECT NO.	CONTROL	REV.	FIGURE
22572560	3000	1	1

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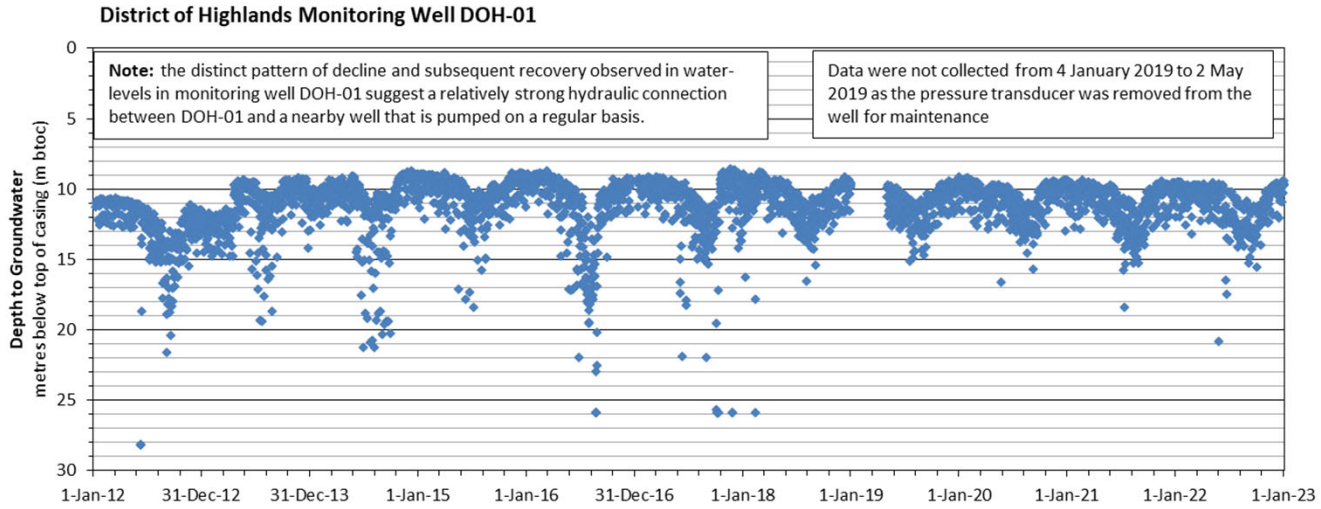

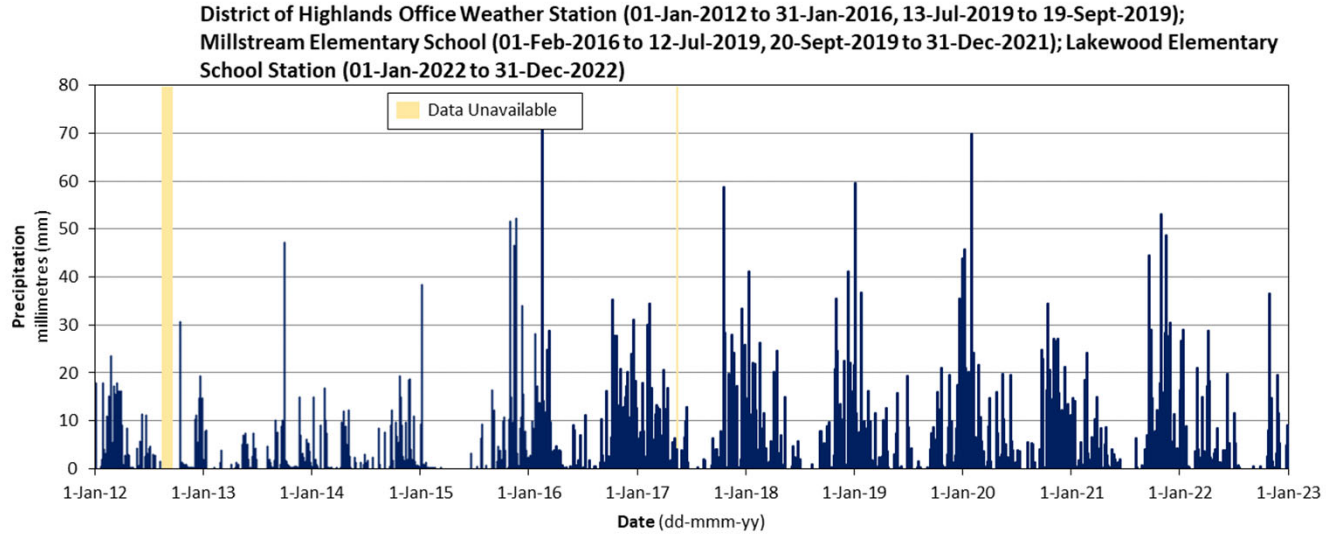

Notes

Water level data collected under the District of Highlands Groundwater Monitoring Program.

Precipitation data obtained online from the University of Victoria School-Based Weather Station Network.
http://www.victoriaweather.ca/

PROJECT	DISTRICT OF HIGHLANDS 2022 GROUNDWATER MONITORING PROGRAM HIGHLANDS, BC				
TITLE	DEPTH TO GROUNDWATER MONITORING WELL DOH-01 AND PRECIPITATION IN SOUTHERN HIGHLANDS				
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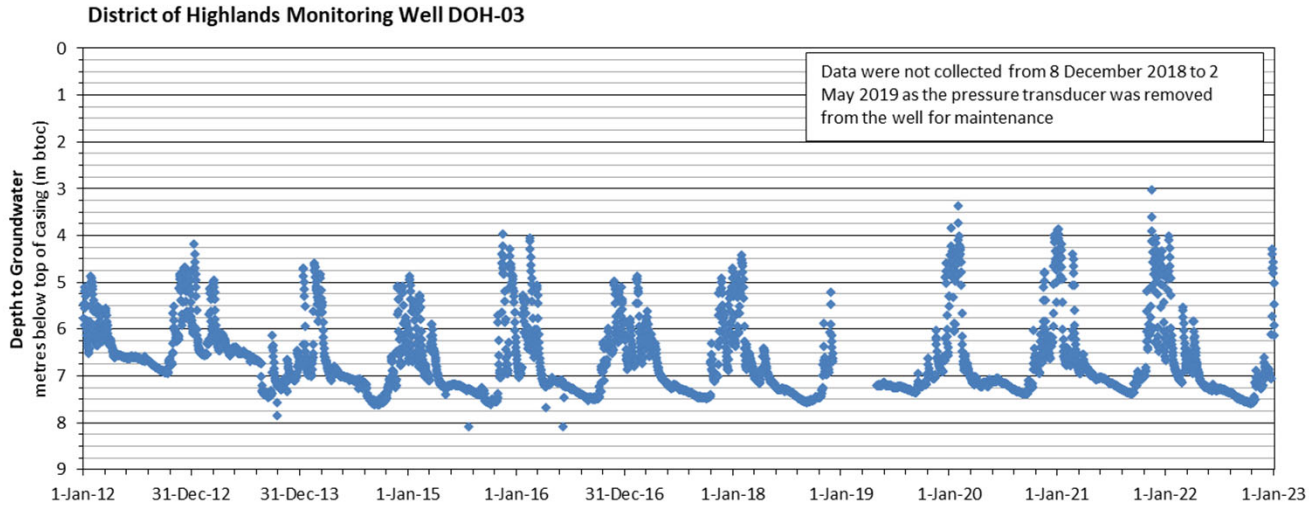
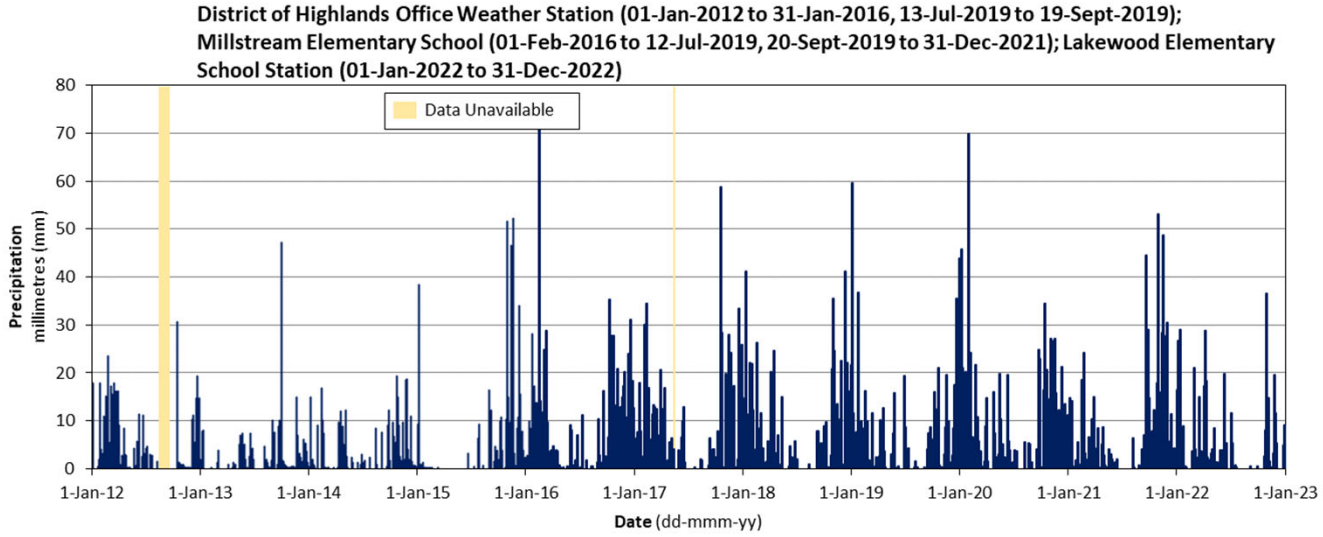
	REVIEW	MB	15AUG23		





Notes

Water level data collected under the District of Highlands Groundwater Monitoring Program.

Precipitation data obtained online from the University of Victoria School-Based Weather Station Network.
http://www.victoriaweather.ca/

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TITLE	DEPTH TO GROUNDWATER MONITORING WELL DOH-03 AND PRECIPITATION IN SOUTHERN HIGHLANDS				
wsp	PROJECT No. 22572560			FILE No. ----	
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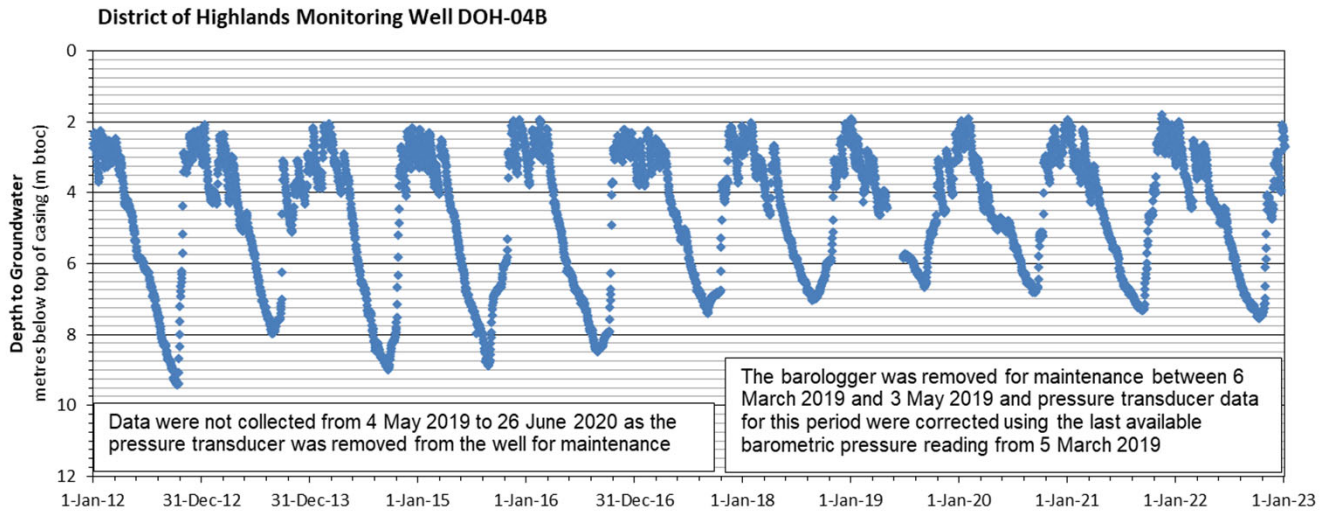

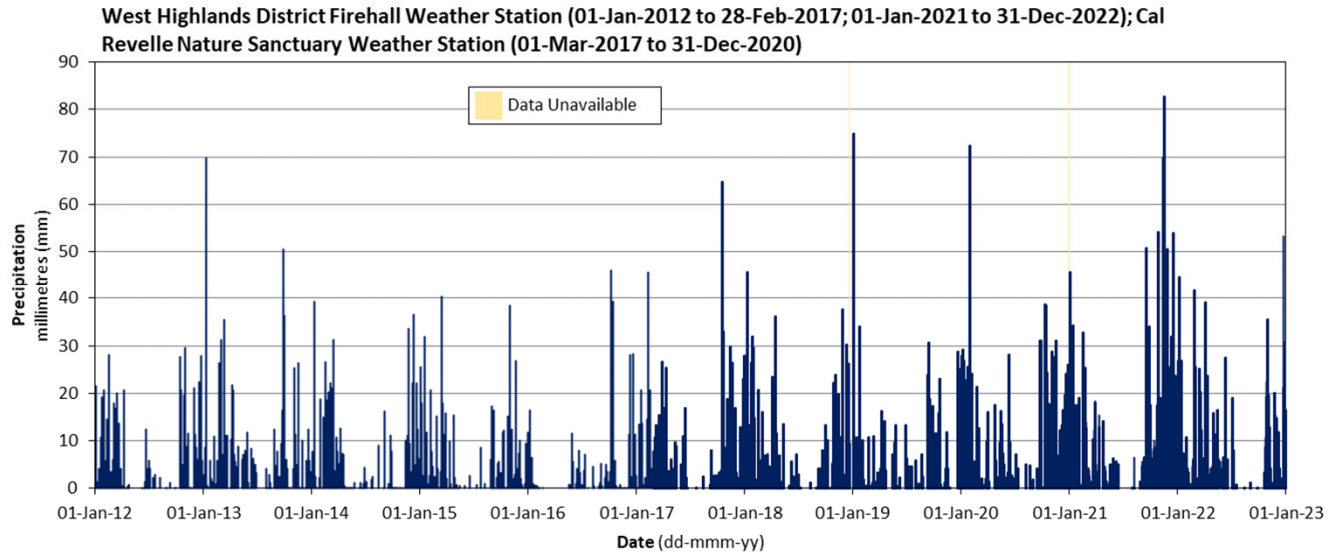

Notes

Water level data collected under the District of Highlands Groundwater Monitoring Program.

Precipitation data obtained online from the University of Victoria School-Based Weather Station Network.
http://www.victoriaweather.ca/

PROJECT	DISTRICT OF HIGHLANDS 2022 GROUNDWATER MONITORING PROGRAM HIGHLANDS, BC				
TITLE	DEPTH TO GROUNDWATER MONITORING WELL DOH-04B AND PRECIPITATION IN WESTERN HIGHLANDS				
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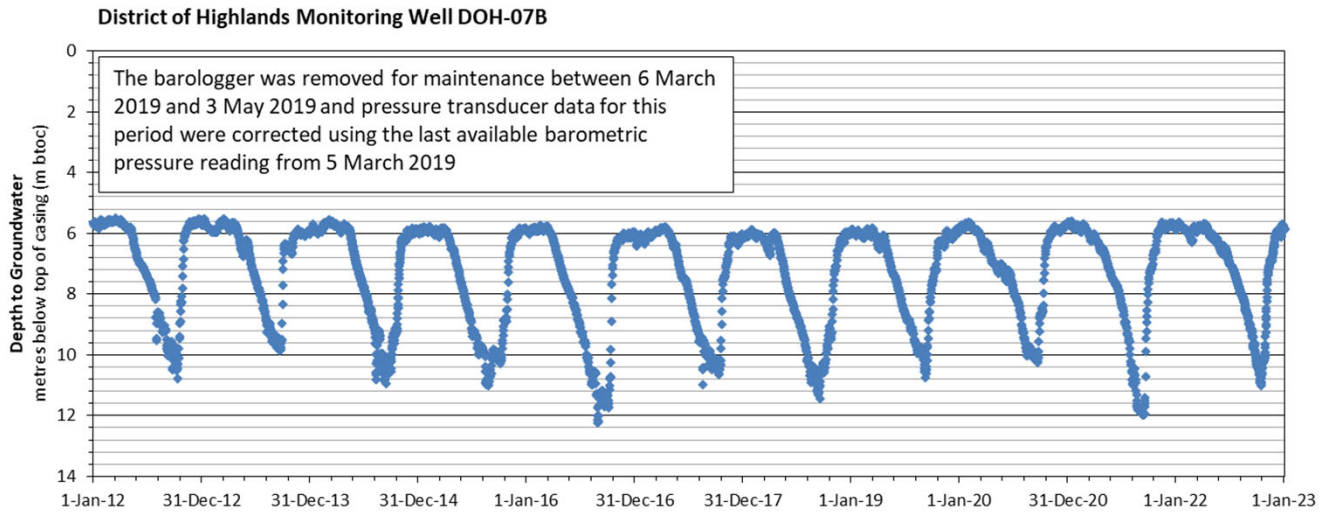

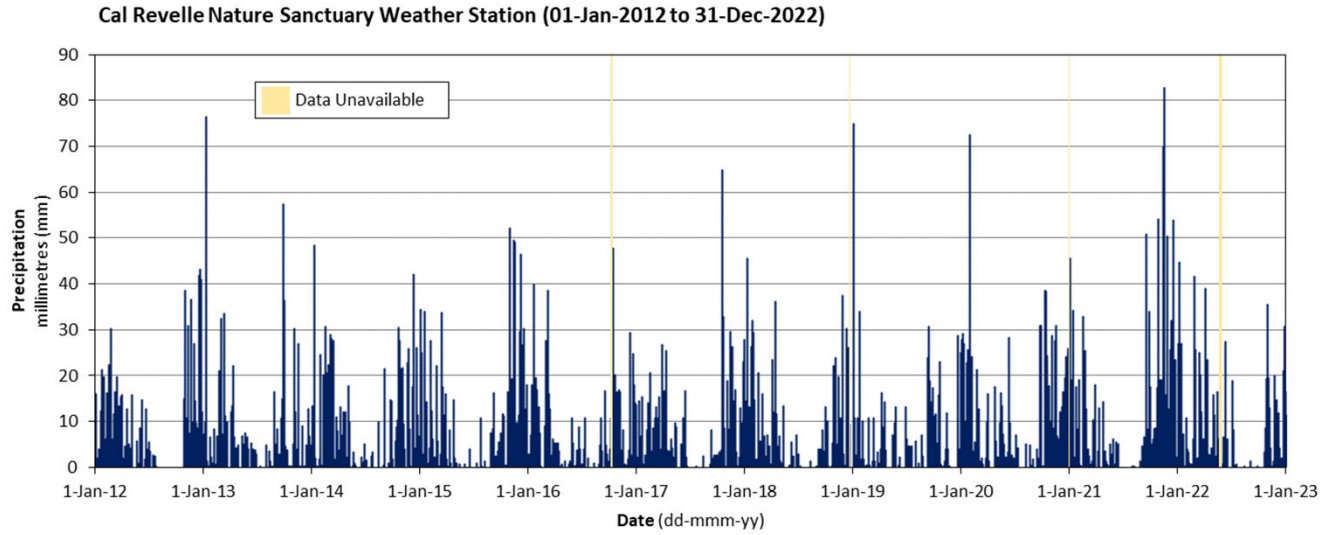

Notes

Water level data collected under the District of Highlands Groundwater Monitoring Program.

Precipitation data obtained online from the University of Victoria School-Based Weather Station Network.
http://www.victoriaweather.ca/

PROJECT	DISTRICT OF HIGHLANDS 2022 GROUNDWATER MONITORING PROGRAM HIGHLANDS, BC				
TITLE	DEPTH TO GROUNDWATER MONITORING WELL DOH-07B AND PRECIPITATION IN NORTHERN HIGHLANDS				
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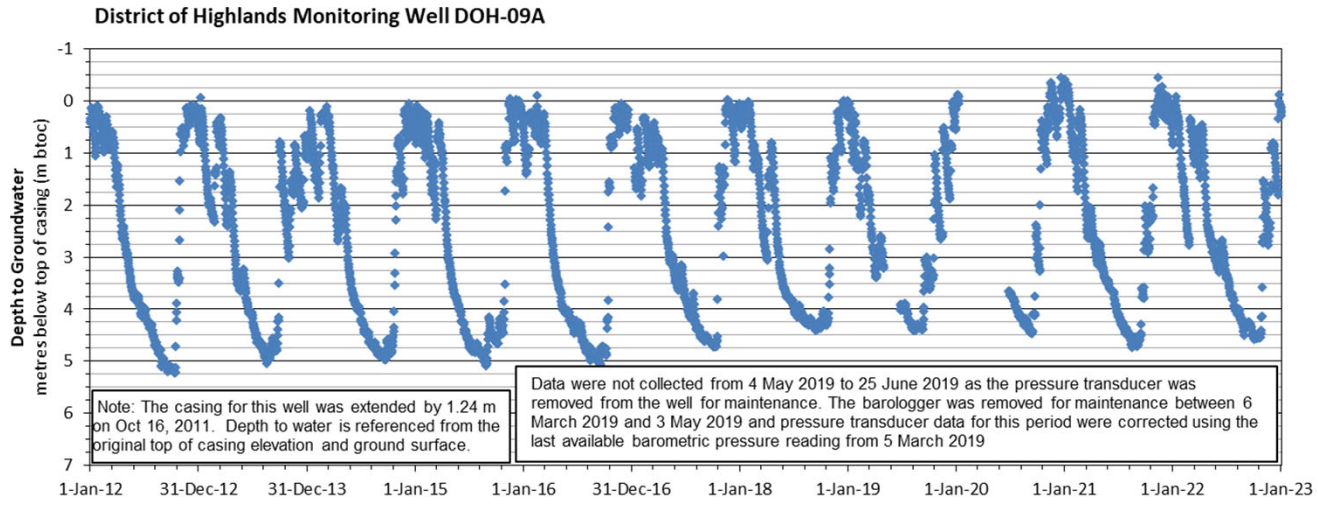
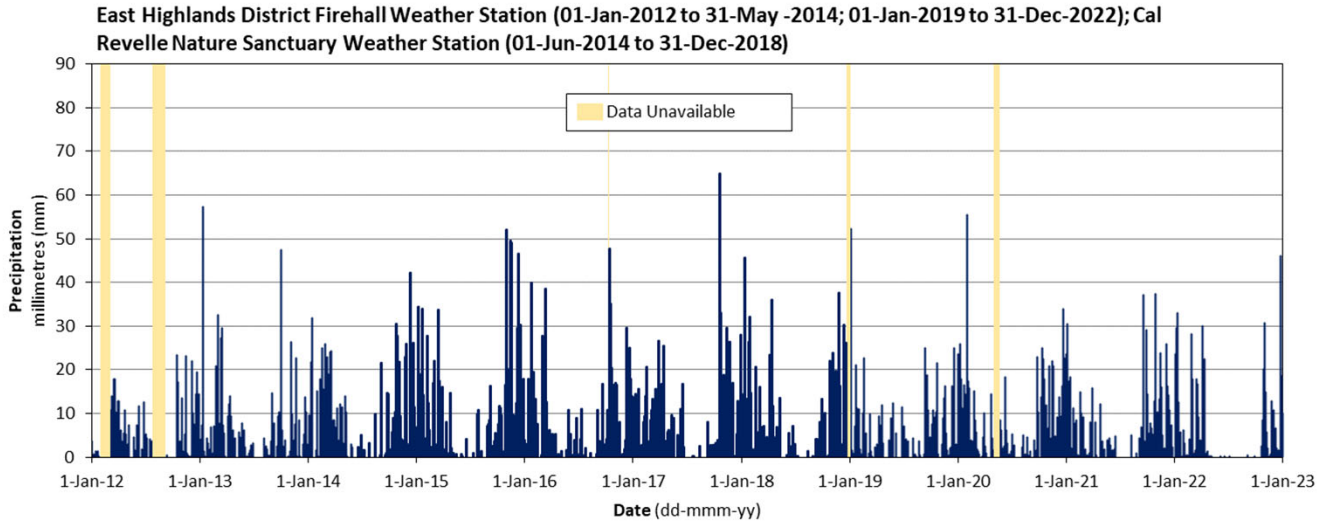
	REVIEW	MB	15AUG23		





Notes

Water level data collected under the District of Highlands Groundwater Monitoring Program.

Precipitation data obtained online from the University of Victoria School-Based Weather Station Network.
http://www.victoriaweather.ca/

PROJECT
DISTRICT OF HIGHLANDS
2022 GROUNDWATER MONITORING PROGRAM
HIGHLANDS, BC

TITLE
DEPTH TO GROUNDWATER MONITORING WELL DOH-09A AND PRECIPITATION IN EASTERN HIGHLANDS

PROJECT No. 22572560			FILE No. ----		
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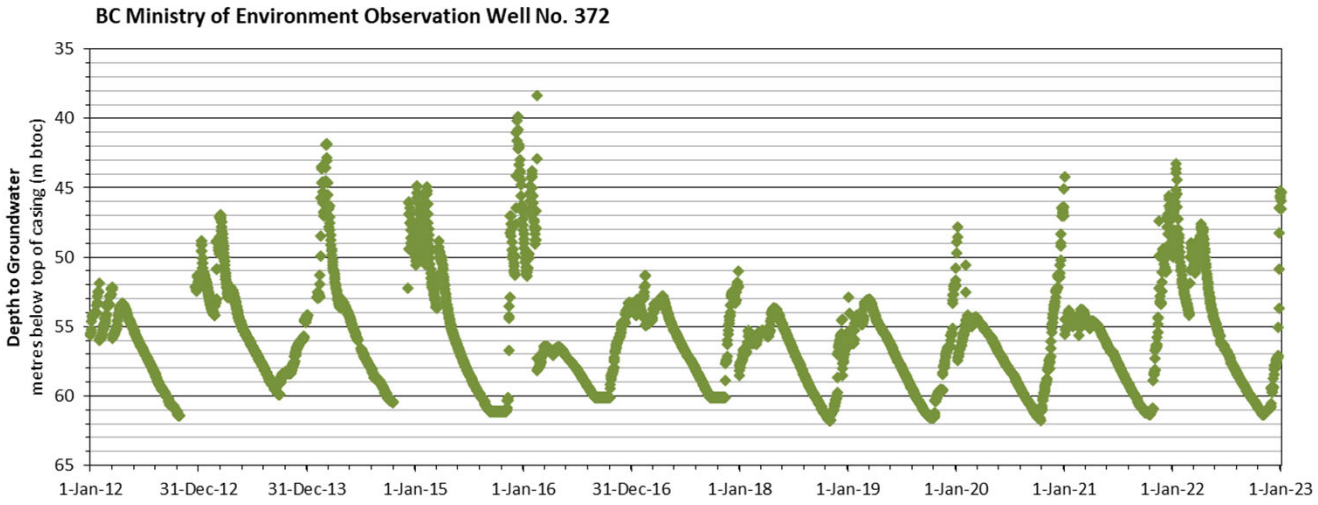
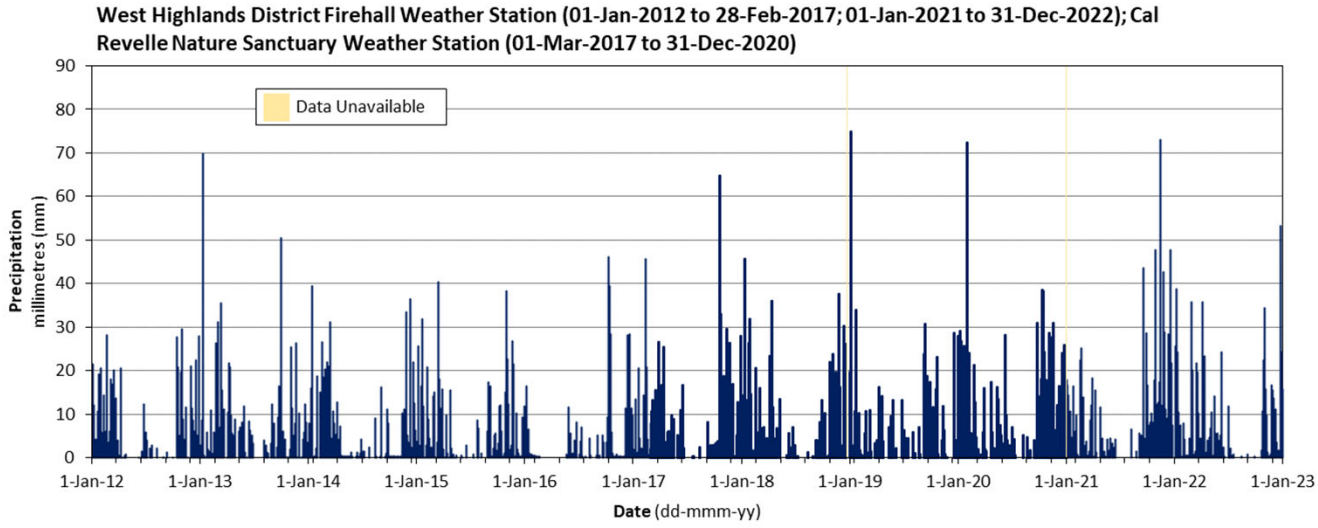
REVIEW	MB	15AUG23			





Notes

Water level data obtained online from the Ministry of Environment British Columbia Groundwater Observation Network.
http://www.env.gov.bc.ca/wsd/data_searches/obswell/map/obsWells.html

Precipitation data obtained online from the University of Victoria School-Based Weather Station Network.
http://www.victoriaweather.ca/

PROJECT	DISTRICT OF HIGHLANDS 2022 GROUNDWATER MONITORING PROGRAM HIGHLANDS, BC				
TITLE	DEPTH TO GROUNDWATER MOE OBSERVATION WELL 372 AND PRECIPITATION IN WESTERN HIGHLANDS				
wsp	PROJECT No. 22572560			FILE No. ----	
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	REVIEW	MB	15AUG23		

ATTACHMENT 1

Conditional Groundwater Licence for Bear Mountain Golf Course

Province of British Columbia
Water Sustainability Act

CONDITIONAL WATER LICENCE

The owner(s) of the land to which this licence is appurtenant is hereby authorized to divert and use water as follows:

a) The aquifer on which the rights are granted is comprised of bedrock materials within the Millstream Watershed (VICT – Millstream) located at approximately 67 metres (220 feet), 84 metres (275 feet), and 116 metres (380 feet) depth below ground surface.

b) The points of well diversions (WTN 79523, WTN 81690, and WTN 95749) are located as shown on the attached plan.

c) The date from which this licence shall have precedence is February 2, 2007.

d) The purposes for which this licence is issued are industrial (lawn, fairway & garden) and land improvement.

e) The maximum quantity of water which may be diverted for industrial (lawn, fairway & garden) purpose is 243,180 cubic metres per year, and for land improvement purpose is 36,520 cubic metres per year.

f) The period of the year during which the water may be used is May 1 to October 31.

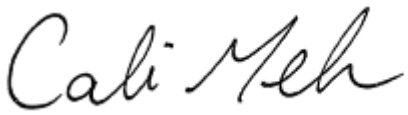
g) The land upon which the water is to be used and to which this licence is appurtenant is Section 5, Range 4 West, Except Parts in Plans VIP60675, VIP67875 & VIP75584; the South 60 acres of Section 6, Range 4 West, Except Part in Plan VIP67875; Section 12, Except Parts in Plans 10853, 11134 & 45402; Section 16, Except that Part in Plan VIP72555; Block B, Section 75; Lot 1, Sections 81, 82 and 84, Plan VIP75509, Except Plans VIP76365, VIP79028, VIP82848, VIP82851, VIP85324, EPP19660, EPP63084, EPP72419, EPP80460 & EPP70640; and Lot 2, Sections 81, 82, 83 and 84, Plan VIP75509, Except Parts in Plans VIP76365, VIP78873, VIP81135, VIP81958, VIP82040, VIP89370, EPP42751, EPP46993, EPP80460, EPP68922 & EPP111201, all within Highland District.

h) The authorized works are three wells, three meters, two ponds, two pumphouses, pipe, and irrigation system, which shall be located approximately as shown on the attached plan.

i) The construction of the said works has been completed and the water is being beneficially used. The licensee shall continue to make regular beneficial use of the water in a manner authorized herein.

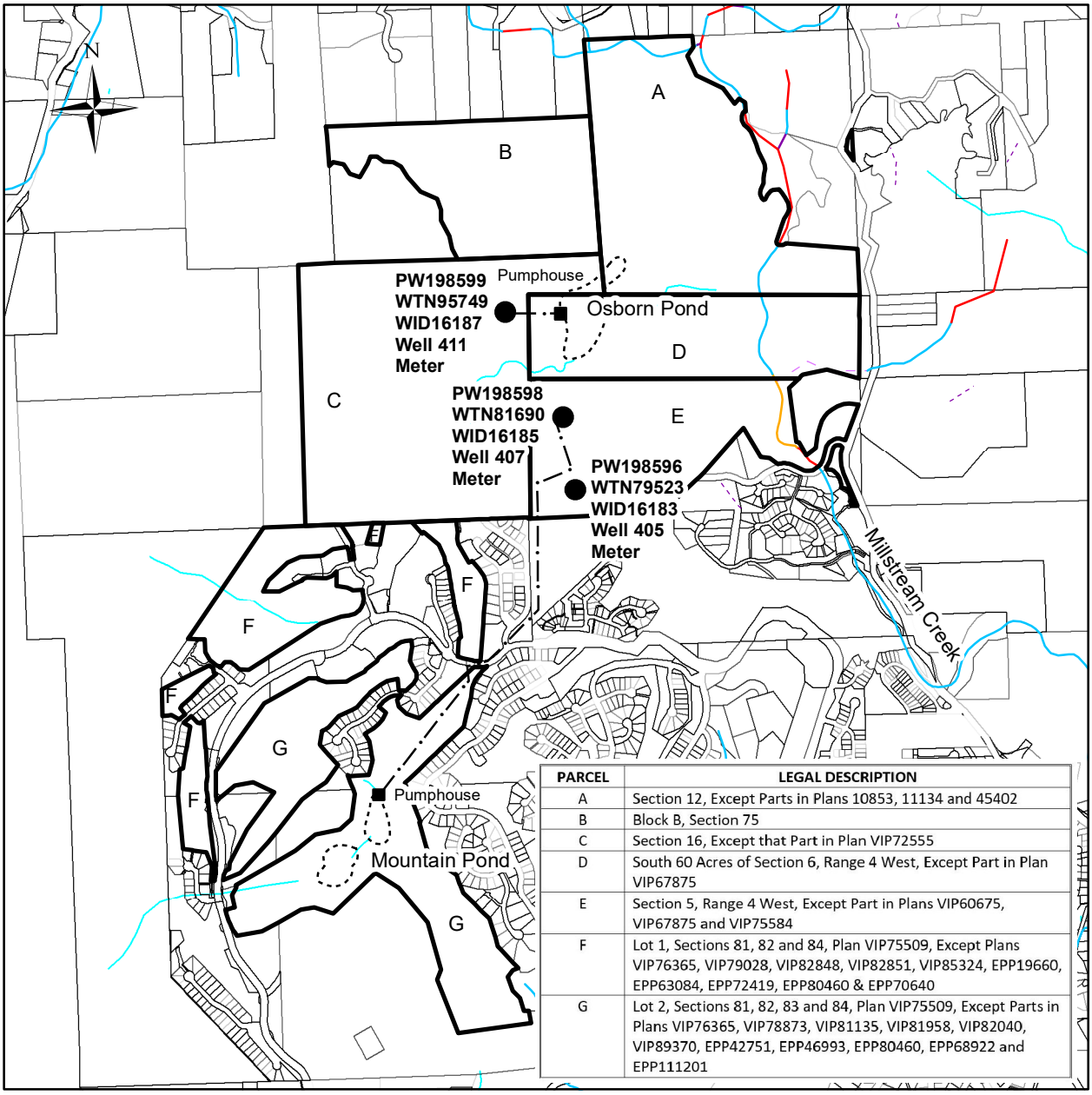
j) The licensee shall install a flow measuring device to the satisfaction of an Engineer under the *Water Sustainability Act*.

k) The licensee shall retain flow meter records for inspection upon request by an Engineer under the *Water Sustainability Act*.



Cali Melnechenko
Water Manager

BRITISH COLUMBIA



PARCEL	LEGAL DESCRIPTION
A	Section 12, Except Parts in Plans 10853, 11134 and 45402
B	Block B, Section 75
C	Section 16, Except that Part in Plan VIP72555
D	South 60 Acres of Section 6, Range 4 West, Except Part in Plan VIP67875
E	Section 5, Range 4 West, Except Part in Plans VIP60675, VIP67875 and VIP75584
F	Lot 1, Sections 81, 82 and 84, Plan VIP75509, Except Plans VIP76365, VIP79028, VIP82848, VIP82851, VIP85324, EPP19660, EPP63084, EPP72419, EPP80460 & EPP70640
G	Lot 2, Sections 81, 82, 83 and 84, Plan VIP75509, Except Parts in Plans VIP76365, VIP78873, VIP81135, VIP81958, VIP82040, VIP89370, EPP42751, EPP46993, EPP80460, EPP68922 and EPP111201

WATER DISTRICT: VICTORIA
PRECINCT: VICTORIA
LAND DISTRICT: HIGHLAND
WATERSHED: VICT - Millstream

Signature: Cali Mele
Date: June 23, 2023

LEGEND:

Scale: 1:20,000
Point of Diversion: ●
Map Number: 92B.043.3
Pipe: ·—·—·—·–

C.L.: 501806
FILE: 20006990

The boundaries of the land to which this licence is appurtenant are shown thus: ——————