

ELANCO ENTERPRISES LTD.

Permit to Practice No: 1001505

4965 Cordova Bay Road, Victoria, B.C., V8Y 2K1

Phone 250 744-1357. E-mail: adakin.elanco@gmail.com

Our File: 308

November 1, 2024

Denman Community Housing Society.

C/o 3771 East Road.

Denman Island, B.C.

V0R 1T0

Attention: David Ricketts. M.Sc., P.Eng. (retired), FEC.

By: e-mail

Dear Sir.

Re: Hydrogeological Assessment of Yield and Source Protection for a Well Located at 1400 Northwest Road, Denman Island, B.C.

As requested, I have conducted a hydrogeological assessment of the area on, and around, the subject property and have determined the sustainable yield from the existing Emcon water supply well. This report is an expansion of the March 5, 2024 report prepared by Elanco Enterprises Ltd in which assessed the Emcon well yield based on pumping tests conducted in December 2023. This preliminary assessment indicated that the well sustain a yield of 0.25 L/s but as the pump test was run during the wetter part of the year a new assessment was required to confirmation that it can sustain this yield all year round and especially during the late summer.

Background:

The Denman Community Housing Society (DCHS) is considering the possibility of developing a residential housing on a portion of the 3361 Piercy Road property owned by Emcon Services Inc (Emcon), on Denman Island. It is understood that the wells on this property have either been abandoned or do not have a sustainable supply of good quality water. For this reason, Emcon has obtained access via an easement to a well located on the 1400 Northwest Road property (the Property). This well is identified by its Well Tag Number (WTN) as Well 34154 or the Emcon Well on Fig. 1. The DCLTA is now exploring the possibility of using this well to supply the potential housing development and requires an opinion on the well's sustainable yield and if the water pumped from this well meets Canadian drinking water criteria.

Work Carried out

This assessment involved reviewing information on regional water wells, surface drainage, soils and geology, visiting the site on November 13th, 2023, supervising a series of pumping tests on the Emcon well, analyzing water level trends and determining a conservative value for a sustainable yield. Four pumping tests were conducted and a brief summary follows:

- 1) Brief high yield (0.5 Litres per second (L/s)) test run on December 5th, 2023 to get an initial indication of the potential short term well yield. The pumped water was discharged near the pump house located on Emcon's 3361 Piercy Road property.
- 2) 5-day test run in December 2023 at a rate averaging 0.18L/s. While this test was run during a relatively wet period of the year, it provided an initial indication of its potential sustainable yield which was used for planning purposes.
- 3) 9-day test run in August 2024 at a rate averaging 0.23L/s..

- 4) Step test run on September 24th, 2024 at rates ranging from 0.25 to 1 L/s.

Following these pumping tests, the water level trends and pumping rates were analyzed and used to assess the long term well yield, the extent of the capture zone and to determine if the well had any impact on the Kirnel Well (WTN 34149). In addition, water quality analyses were performed to assess the discharged water quality.

Location, Topography and Drainage.

The Property is located on the west side of Denman Island; about 200 metres (m) north of the village center, on the 1400 Northwest Road property on the east side of the road (see Fig. 1).

As indicated by the topographic contours on this figure, the Property is located near the western edge of an extensive relatively flat area (the Plateau Area). There are no established natural drainage channels in the Plateau Area and it appears that much of the precipitation falling on this area either seeps into the ground or is evapo-transpired from the local boggy vegetation.

Soils

The regional soils map indicates that the soils on the east side of Northwest Road are a mixture of Tolmie (poorly drained) and Merville (moderately well drained) soils. As there are no well developed surface water channels, it is likely that surface water mostly seeps into underlying sediments and fractured bedrock through the Merville soils.

Bedrock Geology

The bedrock geology of Denman Island consists of sedimentary formations of the Upper Cretaceous Nanaimo Group. These formations are characterized as successions of sandstone-conglomerate units inter-bedded with mudstone and fine-grained sandstone which dip towards the east. The Property is underlain by Cedar District Formation and the ridge located to the northeast is underlain by De Courcy Formation (see Fig. 2). The Cedar District Formation (uKcd) is a massive grey mudstone with occasional siltstone and fine grained sandstone interbeds. The water well drillers often describe this unit as shale. The De Courcy Formation (uKdc) is a massive sandstone with some interbeds of conglomerate.

The Emcon Well

The Emcon well (WTN 34154) on the Property currently supplies water to the Emcon works yard located at 3361 Piercy Road via a pipe that follows an easement on the Property and crosses Northwest Road (see location on Fig. 1). The BC Ministry of Environment's G-wells database has incorrectly assigned the Well Plate Number (WPN) 14340 to Well 27383 located on Emcon's Piercy Road works yard property (see location on Fig. 1). This plate is actually affixed to the Emcon well on the 1400 Northwest Road property (see Photo 1).

The driller's well log of the 32.6m deep and 150mm diameter Emcon Well indicates that it penetrated about 5m of overburden soils before penetrating shale (more likely mudstone) bedrock (see Fig. 3).

There is no indication in the well log that a surface seal was installed. However, given that the overburden sediments are likely very fine and relatively impermeable and that the steel casing

was hammered about 0.3m into the bedrock surface, it is judged that the chances of contaminated nearby surface water entering the well is very low. This assumption was later confirmed by the nature of water level drawdown and recovery trends recorded during the pump tests, as well as the lack of any observed impact on water levels in the nearby dug well during pump tests.

The well log indicates that two water bearing fractures were encountered with one at a depth of about 20.4m and the other at 27.7m. At the time of drilling the estimated yield from the first fracture was about 0.25 L/s and the second fracture yielded an additional 0.13 L/s, for a total of about 0.38 L/s from the completed well.

A drinking water assessment was conducted on this well for the British Columbia Buildings Corporation in 2001 (Kenny, S. 2001) and as part of this process a water sample was collected and analyzed for potability. The results of this detailed water quality analysis are included on Table VII and are discussed later in this report. This assessment did not provide any evidence of contaminated surface water entering the well.

Dug Well

A large diameter dug well is located at a distance of about 9m east of the Emcon Well (see location on Fig. 4 and Photo 2). This well is about 2m deep and there is no record of when it was constructed. The water level in this well was recorded prior to and during and following the both the 5-day and 9-day pumping tests.

Local Area Wells

The locations of identified water wells in the area within a 300m radius of the Emcon well are indicated on Fig. 1 and data on these wells is presented on Table I. It is recognized that many of these wells may not be accurately located and that the static water levels have changed since they were constructed. Also, it is recognized that many of wells are currently not being used and that the yields indicated on the table are likely not sustainable over the long term.

A review of the compiled well information and statistics led to the following observations:

- Of the 10 well records listed on Table I, none indicated a “dry hole” but many did not have a record of the estimated yield.
- The estimated well yields ranged up to 0.75 L/s.
- Well depths ranged from what is likely a shallow dug well (WTN 12994) to a 71.6m deep drilled well.
- The few recorded depths to static water level at the time of well construction ranged from 0.9 to 3.1m.

There are records of two wells on the Emcon’s 3361 Piercy Road property. However, apparently one of these wells does not exist and the remaining well is not used, as the Emcon’s water supply comes from Well 34154 located on an easement on the 1400 Northwest Road property (see Fig. 1).

The well that is located nearest to the Emcon well is the Kirnel Well (WTN 34149). This well is located 150m to the north and is the source of water supplied to 18 properties located along part of Kirk Road and along Nelson Road. The well was originally drilled to a depth of 32.6m but has since been partially back filled and is now about 9m deep. As indicated later in this report, the water level in this well was monitored during all four Emcon well pump testing periods and graphs of water level trends in the Kirnel well are presented on Figs. 5, 8 and 9.

Groundwater Flow Systems

Small fractures and bedding planes in the mudstone bedrock are the principal sources of water, however in many areas, a thin saturated zone in the overburden provides significant storage. The static water levels in most of the wells in the Plateau area are relatively close to ground surface and, as indicated by the blue arrows on Fig. 1, groundwater generally flows orthogonal to the topography in a southwest direction. This is consistent with the presence of a groundwater fed swamp on the northern part of the Property where the dug well and the Emcon Well are located.

It was noted that the elevation of the water level in the dug well in December 2023 was slightly lower than that of the drilled Emcon Well. This suggests that there is an upward flow of water from the fractured bedrock into the nearby swamp-like surface water bodies during this period. However, in August 2024 the piezometric levels in the dug well were only lower than those of the drilled well for brief periods near the middle of each day (see Fig. 9A).

Pumping Tests and Water Level Monitoring

As set out below, four pumping tests were conducted on the Emcon drilled (Well 34154) Two tests were conducted in the fall of 2023 and two in late summer of 2024. Each set of tests were designed to assess both the hydraulics of the well and its sustainable yield. These included both a step test and a sustained pumping test run at a relatively constant rate.

In preparation of the first test, a 25mm diameter PVC sounding tube was installed in the Emcon Well to enable ease of measuring the depths to water in this well while using both an electric sounder tape and automatic recorder. The recorders used for all tests were Solinst dataloggers that had been pre-programmed to record water levels at 1-minute intervals. For the fall of 2023 testing program the logger in the Emcon well was installed on November 28th and for the long term test in late summer of 2024 it was installed on August 7th. A data logger was reinstalled in the Emcon well on September 24th, 2024 to conduct a step test. At the start of both testing periods a Solinst datalogger was also installed in the dug well and set to read at the same frequency.

In 2023 the loggers remained in place until 25th of December when they were removed after a 5-day pumping test was concluded. The loggers ran out of memory on December 22, 2023 and hence datalogger water level readings for the last day of the pumping, and the subsequent water level recovery periods were not available. Only intermittent manual measurements are available for this period (see graphs on Figs 6A and 6B).

In 2024 the logger was removed from the well on August 29th, which was 4 days after the 9-day pumping test was completed. A graph of this record is presented in Fig. 9A.

In order to assess the potential impact that pumping from the Emcon Well might have on the Kirnel Water system, Steve Morgan (the manager) agreed to provide the 10-minute water level recorder data for their well during both testing periods. A plot of the 2023 record is presented on Figs. 5B and 8B and the 2024 record is on Fig. 9B.

Pumping Testing and Data Processing Procedures

As Emcon needed a water supply during the testing periods it was not feasible to divert water at the well head for an extended length of time. This meant that the water could not easily be diverted around a pressure tank installed in the pump house located on Emcon's Piercy Road works yard (see location on Fig. 1 and Photo 3). The discharge from the well during the first three tests was directed into a small bush covered area near the pump house (see Photo 4). A bucket and the time taken to fill the known volume were used to determine the flow rate. While the pumping rate from the Emcon well varied, the flow from the pressure tank was relatively constant during the multi-day tests. The controls on the existing pump in the Emcon Well and a sensor in the pressure tank resulted in a cyclic pumping from the well for 3 minutes followed by an eight minute discharge from the pressure tank (see graphs on Figs 6D and 10B).

The data from the dataloggers in the Emcon Well, Kirnel Well and Dug Well were downloaded and after correcting for barometric pressure, the recorded pressures were converted to geodetic water levels using estimated top of casing elevations.

Details of Pumping Tests

Test 1- Initial Yield Test (2023)

In preparation of the extended pump test and to get an indication of its potential yield, the Emcon Well was pumped for a 30 minute period at a maximum rate of 0.75 Litres/sec (L/s) on December 5, 2023. The water level responses during this brief period are presented on Fig. 6. This data indicated that the well had a potential to pump at least 0.3 L/s and provided useful information for the design of the longer term pumping test that began on December 18th, 2023. Graphs of this record are presented on Figs. 7A and 7B.

Test 2- Five-day pumping Test (2023)

A 5-day pumping test commenced on December 18th, 2023. During this test the flow rates and occasional manual depths to water in the well were recorded by a local volunteer (Dave Ricketts) and a summary of this record is presented on Table II. As can be seen, the recorded flow rate was not constant and ranged from 0.07 to 0.29 L/s, and the average and median pumping rates were 0.18 and 0.15 L/s respectively. The water levels recorded in the drilled well varied considerably which, as is indicated above, is the result of the pump being periodically shutdown when the pressure in the pressure tank reached a preset maximum. This resulted in a relatively constant discharge but fluctuating water levels in the Emcon well as is indicated on Figs 6A, 6B and 6C..

A water sample was collected near the start of the 5-day test and one collected at the end of the test. Both samples were later analyzed for pH, redox and electrical conductivity and the results are presented on Table VII.

Test 3- Nine-day pumping Test (2024)

A 9-day pumping test commenced on August 16th, 2024. This test was conducted using the same arrangements as per the 2023 5-day test. Again the water levels in the well fluctuated but the discharge was relatively constant. A summary of the field measurements are presented on Table III and this shows that the average pumping rate was 0.23 L/s. A graph of water level elevations prior to, during and following the test is presented in Fig. 9A.

A water sample was collected at the start of the 9-day test and one was collected while the test was in progress on day 2. Both samples were sent to a commercial laboratory for water quality analyses and the results are presented on Table VII. The first sample was analyzed for electrical conductivity, TSS and sodium and the second was for a complete potability analysis. In addition, a sample was collected at the end of the test and analyzed for electrical conductivity.

Test 4- Step Test (2024)

A four rate step test was run on September 24, 2024. As this was run over a few hours and would not have an impact on Emcon's water supply it was feasible to intercept the discharged water at the well head and to eliminate the impact of the pressure tank. The well head installation is illustrated in Photo 5 and the water discharge location is illustrated in Photo 6. A summary of water level and discharge measurements is summarized in Table IV and graphs of water level and flow rate trends are presented on Fig. 12.

Water Level Trends

Fall of 2023

A review of the water levels prior to the start of the 5-day pumping test as presented on Figs 5 and 6 show the following:

- 1) The water levels in the Emcon drilled well and the dug well responded to rainfall events.
- 2) The operations on the Emcon property require the Emcon well to pump for brief periods every day or two and after each pumping event the water level recovers rapidly.
- 3) The Kirnel Well was pumped once every day and the well took a few hours to recover after each pumping event.
- 4) The water levels in all three wells rose slightly over the 21 day period prior to the commencement of the 5-day pump test.
- 5) Both wells responded to daily rainfall events.

As can be seen from these graphs, pumping from the Emcon Well had no impact on the water levels in the nearby dug well and the Kirnel well, which is located 150m away.

Water Level Trends During the 5-Day Pump Test

As can be seen in the graphs presented on Fig 6, the water level in the pumped well fluctuated during the test. As indicated on Table II, the pumping rate started at 0.24 L/s but did not remain constant, with the rate fluctuating between about 0.08 and 0.24 L/s. These changes were related to a combination of adjusting the valve on the discharge pipe and the sensors in the pressure tank. As the test proceeded the maximum pumping rate was increased to 0.29 L/s. The average and median rates during the 5-day period were 0.18 L/s and 0.15 L/s respectively.

As can be seen on Fig. 6D the water level typically followed an 11 minute cycle with it declining for 3 minutes and then recovering for 8 minutes. As indicated on the bottom of Table II this indicates that the operating storage volume in the pressure tank was about 85.4 Litres and that the estimated pumping rate during the 3 minute refill period will have been about 0.65 L/s.

The maximum drawdown recorded during the 5-day pumping period was about 6m. In spite of the pumping rate fluctuations the specific capacity over the last two days remained constant at about 0.028 L/s/m (see Table II)..

Water Level Trends During the 9-Day Test Conducted in August 2024

As would be expected, the water elevations were about a metre lower than they were in December 2023. The water levels in both the drilled and dug wells during the 20 day 2024 monitoring period declined by about 0.2m. The series of drawdown spikes that can be seen on the Fig. 9A graph, prior to and after the pumping test were the result of pumping for the Emcon facility water supply.

As with the 5-day 2023 pumping test the water levels during the test fluctuated over a range of about 3m over an 11 minute cycle but did not show any evidence of a decline as the test proceeded (see Figs. 9A and 10A and 10B).

The average and median pumping rates over the 9-day pumping period were 0.23 and 0.22 L/s respectively. As indicated on the bottom of Table III this indicates that the operating storage volume in the pressure tank was about 108 Litres and the estimated pumping rate during the 3 minute refill period will have been about 0.83 L/s.

The water level during the post test recovery was used to estimate the aquifer transmissivity. As set out in the table on Fig. 12 the initial apparent transmissivity (Recovery Leg 1 on the graph) was about $8.4 \times 10^{-6} \text{ m}^2/\text{s}$ and for the latter part the transmissivity was $3.2 \times 10^{-5} \text{ m}^2/\text{s}$. As the well casing holds 18.5 litres per metre of casing the corrected initial transmissivity is about $1 \times 10^{-5} \text{ m}^2/\text{s}$.

Water Levels and Pumping Rates During September 2024 Step Test

As indicated in Table VI and on Fig. 12B, the step test was run at four different pumping rates for 30 minutes that ranged from 0.26 to 1.0 L/s. The specific capacity at the end of each step ranged from an initial 0.086 L/s/m down to 0.062 L/s/m at the end of the test. The pumping level in the well at the end of the test was about 2m above the principal water bearing fracture in the well (see Fig. 3 and graphs on Figs. 12B and 12C).

The drawdown vs. pumping rate graph (Fig. 12D) shows that the relationship between these two parameters is linear except for the last rate. This confirms that the well is relatively efficient and can sustain a rate much greater than the average 0.23 L/s pumping rate during the 9-day test.

The drawdown trend during the first step of the test and the well recovery after the test were used to estimate the aquifer transmissivity. As set out in the Table at the bottom of Fig. 12 the apparent transmissivity is $8.4 \times 10^{-6} \text{ m}^2/\text{s}$ for the steeper portions and in the flatter portions the range is from 1.5×10^{-5} to $3.9 \times 10^{-5} \text{ m}^2/\text{s}$. After accounting for the well casing volume the corrected initial transmissivity is about $1 \times 10^{-5} \text{ m}^2/\text{s}$.

These values compare relatively well with the transmissivity values listed on Fig. 11

Potential Impact on the Kirnel Well

A graph of water levels recorded in the Kirnel well for the period August to September 2024 is presented on Fig. 9B. This graph clearly shows the impact of the well being intermittently pumped. Also of note is that when the pumping frequency increases the water level in this well is slightly depressed. The red arrows on Fig. 9B span the most significant high frequency periods. While one of these periods almost coincides with the start of the 9-day pumping tests the others do not. The graph presented on Fig 13 clearly illustrates that pumping at a rate of 0.23 L/s from the Emcon Well does not have an impact on the Kirnel well.

The transmissivity values obtained from the well recovery and step tests (see Figs. 11 and 12) were inserted into the Theis equation to estimate the potential drawdown at a distance of 150m from the Emcon well and the results indicated that the potential drawdown would be a few centimeters after 100 days of pumping which essentially equates to no impact on the water levels in this well.

Preliminary Assessment of Long Term Well Yield.

As indicated on Table V, the available drawdown is 22.2m. This is the distance between the static water level and the first water bearing fracture zone. The standard practice for calculating the long term yield of a well is to use 75% of the available drawdown and an estimated specific capacity based on a projected 100-day pumping of the well. As the pumping test was not pumped at a constant rate the 100-day specific capacity of 0.06 L/s/m had to be estimated using both available data and experience with assessing other wells with a similar hydrogeological setting. As indicated on Table V by assuming a conservative long term yield of 0.25 L/s the calculated drawdown after 100 days would be 4.2m. This is only a fraction of the 16.2m available drawdown based on 75% of the available drawdown of 21.6m.

As the average pumping rates during the two multiday pump tests averaged 0.18 and 0.23 L/s it is considered unreliable to rate the sustainability of the Emcon well much higher than the conservative rate of 0.25 L/s (4 USgpm).

Precipitation and Local Aquifer Recharge

The precipitation at the site is likely similar to that recorded at the Comox International Airport. The long term 30 year climate normals for monthly total precipitation (mm) at the Comox Airport Station are: Jan (171.9), Feb. (114.3), Mar (105.7), Apr (64.6), May (45.6), Jun (42.8), Jul

(26.7), Aug (29.2), (Sep (41.8), Oct (122.8), Nov (200.5) and Dec (187.9) and the annual average is 1,153.6 mm.

As indicated on Fig. 5A, rainfall during the 2023 monitoring period clearly had an impact on the water levels in both the dug well and in the Emcon drilled well. There was very little rainfall during the August and September 2024 monitoring period, resulting in a gradual decline in water levels in both the Emcon and Kirnel wells (see Figs. 9A, 9B and 9C). The exception was a rise in the Kirnel well following the September 25th rainfall event.

Based on experience in other areas, during the winter months a relatively flat area with Tolmie and Merville soils will become saturated and typically between 15 to 40% will recharge the aquifer. Based on an assumption of a 20% recharge factor and an aquifer transmissivity of $3 \times 10^{-5} \text{ m}^2/\text{s}$, the calculated width of the capture zone for the well pumping at 0.25 L/s would be about 167m and the length about 205m (see calculations on Table VI and the extent of zone plotted on Fig. 1). The distance from the Emcon Well to the contact bluff located northeast of the well is about 420m, which suggests that there is an adequate recharge area to sustain more than the estimated 0.25 L/s well yield.

Groundwater Quality

Water samples were collected from the Emcon Well at the start and end of the 5-day pumping test. Both samples were later analyzed for pH, ORP and electrical conductivity (EC) and the results are presented on Table VII. No potability analysis was conducted during the 2023 testing period as a sample had been collected from a tap located at the Emcon pump house in 2001 (Kenny, S, 2001). The results of this very detailed analysis are also presented on Table VII.

Water samples were also collected at the start of the 9-day test, after two days of pumping and at the end of the test. The first two samples were sent to a commercial laboratory. The first sample was analyzed for selected indicator parameters and the second for a complete potability analysis and the results are summarized on Table VII. The third sample was analyzed using a portable meter for electrical conductivity and the results are presented in Note 6 at the bottom of Table VII.

The following are comments on the results of the water quality analyses:

- Water quality is good and the only item that did not meet the Canadian Drinking Water Quality Maximum Acceptable Concentration criteria (MAC) is the presence of coliform bacteria. However, as both potability samples (in 2001 and 2024) were collected from a tap and not at the well head, the source of coliform and other bacteria is most likely in the piped water supply system and not in the aquifer.
- As is noted in the Kenny report, the results of routine coliform tap water testing carried out by the local Environmental Health Officer over the period February 1997 and May 2001 showed that no coliforms were detected in any of the 15 water samples. However, two samples collected by local staff in 1996 did have some coliform present. Also the sample collected in 2024 had coliform bacteria present. The difference between grab samples and

professionally collected routine samples most likely can be explained by the sampling techniques used by the sampler.

- The chloride concentrations in the 2001 and 2024 water samples were relatively high at 190 and 216 mg/L respectively, but both were below the 250 mg/L the Aesthetic Objective (AO) concentration, which is primarily based on taste and is not a health issue.
- Similarly, the sodium concentration in the 2001 water sample was high at 206 mg/L. However, the concentrations in both of the two 2024 samples were 144 and 173 mg/L. The 2001 sample was slightly over the 200 mg/L AO guideline concentration but the 2024 samples were both below. As with chloride, this AO limit is primarily based on taste and is not a health issue.
- The water sample collected at the start of the 5-day 2023 pump test had an electrical conductivity (EC) of 540 $\mu\text{S}/\text{cm}$ and the sample collected at the end of the test had an EC of 951 $\mu\text{S}/\text{cm}$, while the sample collected on 2001 had an EC of 925 $\mu\text{S}/\text{cm}$. Similarly, the EC at the start of the 2024 test was 741 $\mu\text{S}/\text{cm}$, the second sample had an EC of 1030 $\mu\text{S}/\text{cm}$ and the EC in the sample at the end of the test was 1092 $\mu\text{S}/\text{cm}$. These increases are more likely related to the pumping rates during the preceding periods, with the concept that higher pumping rates result in more salty water being drawn from the lower (potentially salty) fracture in the well.

Experience with assessing the origins of salty water in Gulf Island fractured bedrock aquifers suggest that salts trapped in the bedrock for millions of years are trapped in the rock and are slowly leached out as groundwater passes along the fractures (Dakin et al., 1983). In general, sustained flushing of water along the fractures when a well is being pumped will result in a lowering the salt content. There are many case histories of Gulf Island wells having declining salinity over time especially after a well goes into a higher rate of production.

Andrew Slater (the former manager of the Kirnel water system) indicated that the Kirnel well initially had relatively salty water and after the lower part of the well was filled in, the water quality improved substantially.

If the saltiness of the Emcon well became an issue in future, consideration could be given to sealing off the lower fracture (yielding about 0.13 L/s) in the well and relying on water coming from the upper fracture (yielding about 0.25 L/s) (see Fig. 3).

A record of a water quality analysis of a sample collected from Well 27383 located on the Emcon works yard property is presented on Table VII. Many of the parameters analyzed in this sample had concentrations similar to that of the Emcon Well. The most significant differences were the low chloride and sodium concentrations in well 27383 and the higher iron and manganese concentrations in the same well.

Water Supply to Proposed Housing Project.

As indicated previously, it is recommended that a conservative sustainable yield from the Emcon Well is 0.25 L/s or 21,600 L/day be used for planning. As indicated on Table VIII a reasonable per capita water usage for a small housing unit on a Gulf Island is about 150 L/day. An analysis of the pumping events in the water level record during the pre pumping period

suggests that the Emcon staff current pump from their well is about 60 Litres per day, which is very small when compared with the potential well yield of 21,600 L/day.

The 150 L/day/person usage for housing does not include any allowance for irrigation usage during the summer. The records for housing units in the Regional District of Nanaimo and in the southern Gulf Islands suggests that the water consumption could increase by a factor of between 1.5 and 2 during the peak summer months where some irrigation is required.

If there was no need for irrigation and the well could sustain a 0.25 L/s rate, then the housing could theoretically serve a population of 144 and, if there was a need for a significant amount of irrigation, the population could be reduced by as much as a half.

Summary and Conclusions

1. The log of the Emcon Well indicated the presence of two deep fracture zones in the 32.8m deep well and an estimated the short term yield of 0.38 L/s.
2. There is no evidence that a 5m deep surface seal has been installed around the well casing, as is required by existing well construction regulations.
3. The two short term high rate pumping tests and the two multiday pump tests have provided a strong indication of the Emcon can sustain a yield of at greater than 0.25 L/s yield or 21,600 L/day.
4. The water requirement for a typical small scale housing unit on the Gulf Islands is about 150 litres per person per day. If there was no need for irrigation, this suggests that the well could theoretically support a housing facility with a population of up to 144.
5. The Emcon Well water meets Canadian Water Quality Maximum Acceptable Concentration criteria for all inorganic parameters. While the samples indicate that they have coliform bacteria and do not meet the guideline, it is judged that the source of coliform is from the piped system and not the aquifer.
6. The well water has an elevated salt content that has sodium and chloride concentrations at or, slightly above, the aesthetic objectives. However, the saltiness is expected to gradually decline when the well is put into production.
7. When the Emcon well is pumping at a rate of 0.25 L/s the estimated width of the capture zone is 167m and this extends about 20 m into the Plateau area located northeast of the well.
8. As the water levels in the nearby dug well were not impacted during the extensive pumping from the Emcon well, there is no evidence to suggest that this well will be classified as being Groundwater at Risk of Containing Pathogens (GARP). If it did it would require additional preventative measures to be installed in the water treatment system.
9. There was no evidence of pumping from the well having an impact on either the Kirnel well or the local surface water drainage system.

November 1, 2024

Recommendations

1. The area around the existing well should be re-contoured with low permeability soil with a surface graded away from the well casing to a distance of about a metre.
2. Emcon should be consulted to determine their future water needs.
3. Prior to commissioning a water supply, the well and the pipe leading from the well to the pump house should be shock chlorinated to remove potential bacterial growth.
4. If the well water salinity becomes an issue in future, consideration should be given to the feasibility of plugging the lower fracture zone
5. If a higher well yield is required in future, consideration should be given to diverting the discharge at the well head and running a 3-day test at a rate higher than 0.25 L/s during a dry time of the year.

Limitations.

This investigation has been conducted using a standard of care consistent with that expected of scientific and engineering professionals undertaking similar work under similar conditions in B.C. No warranty is expressed or implied.

I trust that this is sufficient for your present purposes

Yours truly,

Elanco Enterprises Ltd.



R. Allan Dakin, FEC, P. Eng.
Senior Groundwater Engineer



Att.

References and Background Reports

- Allen, D.M. and Matsuo, G.P. 2001. Results of the Groundwater Geochemistry Study on Hornby Island, British Columbia. Report prepared for Islands Trust, Victoria. 119 pp.
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Constant Rate Test Photos
(taken on August 18, 2024)



Photo 1. Emcon Well Head (WTN 34154 WPN 14340)



Photo 2. Wooden enclosure around the Dug Well with depth to water measurement in progress.



Photo 3. Pressure tank in pump house on Emcon's 3361 Piercy Road property



Photo 4. Discharge pipe near the pump house during the 9-day pumping test.

Step Test Photos

(taken on September 24th, 2024)



Photo 5. Emcon well head during step test with water level measurement in progress.



Photo 6. Emcon well with measuring bucket and discharge pipe.

Tables

Table I
Summary of Local Area Well Information

Well Tag Number	Well ID Plate	Construction Start Date	Owner	Address		Depth to (m)				Elevation (m-asl)					Yield L/s
				Number	Road	SWL	Bedrock	PWS	Bottom	Ground	SWL	Bedrock	PWS	Bottom	
12994		1-Jan-50	Emcon	3361	Piercy	na	na	na	na	43	na	na	na	na	na
27383		4-Dec-72	Emcon	3361	Piercy	na	2.4	29.9	71.6	42	na	40	12	-30	na
34149	13927	1-Jan-76	Kirnel	1400	Northwest	2.33	6.4	9.1	44.8	46	44	40	37	1	0.75
34154	14340	1-Jan-76	Emcon	1400	Northwest	1.34	4.9	27.7	32.6	44	43	39	16	11	0.38
41516		1-Jan-79		1536	Northwest	na	6.1	25.9	32.0	46	na	40	20	14	0.06
68240		25-May-92		1607	Northwest	0.91	3.4	17.4	22.9	43	42	40	26	20	0.19
70554		16-Jan-90		1536	Northwest	na	1.52	27.4	30.5	46	na	44	19	16	0.13
70555		17-Jan-90		2830	Piercy	1.22	2.13	22.9	30.5	40	39	38	17	10	0.06
70556		19-Jan-90		2830	Piercy	3.05	1.22	58.5	61.0	40	37	39	-19	-21	na
93687	13927		Kirnel	3176	Kirk	See Note 3.									0.38

Notes

- 1) See locations of wells on Fig, 1
- 2) The Well Plate Tag on the 34154 well is the same as that listed for Well 27383 on Emcon property and has been reassigned.
- 3) This well likely does not exist and most of the information on well log is consistent with Kirnel Well (WT34154) and the address provided is the contact person for the Kirnel water system

Table II

Monitoring information During December 2023 5-Day Pump Test on Emcon Well (WTN 34154)

Day	Time	Depth to Water (m)		DD m	Pumping rate		Water Elevation (m-asl)		SPC L/s/m	Comments
		Drilled	Dug		US gpm	L/s	Drilled	Dug		
18-Dec-23	10:00 AM	0.85	0.81	0	0		43.15	42.79		SWL
18-Dec-23	10:40 AM				3.75	0.24				
18-Dec-23	10:50 AM									Water sampling
18-Dec-23	2:45 PM	1.34	0.81	0.49	1.33	0.08	42.66	42.79	0.169	Pumping
18-Dec-23	3:55 PM				3.75	0.24				
19-Dec-23	9:48 AM				2.20	0.14				
19-Dec-23	9:58 AM	2.50	0.81	5.42			41.50	42.79	0.026	
19-Dec-23	10:20 AM				3.20	0.20			0.048	
20-Dec-23	10:15 AM				1.15	0.07				
20-Dec-23	10:24 AM	2.16	0.81	4.32			41.84	42.79	0.017	
20-Dec-23	10:37 AM				3.33	0.21			0.048	
21-Dec-23	9:40 AM	1.98	0.81	3.72			42.02	42.79	0.036	
21-Dec-23	9:50 AM				2.10	0.13				
21-Dec-23	10:09 AM				4.60	0.29				
22-Dec-23	9:53 AM				2.46	0.15			0.028	
22-Dec-23	10:01 AM	2.53	0.81	5.52			41.47	42.79		
22-Dec-23	10:09 AM				4.60	0.29				
23-Dec-23	10:08 AM									Water sampling
23-Dec-23	10:10 AM				2.4	0.15				
23-Dec-23	10:20 AM	2.44	0.81	5.22			41.56	42.79	0.029	
23-Dec-23	10:31 AM									Pump off
23-Dec-23	10:41 AM	2.19		4.42	0		41.81			
23-Dec-23	10:51 AM	2.07		4.02	0		41.93			
24-Dec-23	9:51 AM	0.94		0.32	0		43.06			
While Pumping	Minimum	1.34	0.81	0.49	1.15	0.07	41.47	42.79	0.02	
	Average	2.16	0.81	4.12	2.83	0.18	41.84	42.79	0.05	
	Median	2.30	0.81	4.77	2.46	0.15	41.70	42.79	0.03	
	Maximum	2.53	0.81	5.52	4.60	0.29	42.66	42.79	0.17	

Notes:

- 1) See locations of wells on Figs.1 and 4.
- 2) Elevation of top of well casing assumed to be = 44.0 m-asl DD = Water level drawdown in drilled well
- 3) Elevation of dug well measuring datum = 43.6 m-asl SWL = Static water level

Pumping Cycle Activity (minutes)

Recovery	8	In order to sustain a rate of 0.18 L/s over 8 minutes		
Pumping	3	the storage volume in the tank must be =	85.4	Litres
Total	11	Pumping rate required to fill the pressure tank =	0.47	L/s
		Rate for filling the tank and sustaining the flow =	0.65	L/s
			10.4	USgpm

Well Monitoring During August 2024 9-day Pumping Test

Date	Comments	Depth to Water (m)	Elev (m)	Comments	Time	Rate (USgpm)
2023-11-29			44.00 43.60	Assumed elevation top edge of well casing Top of Stake		
2024-08-16		1.38 1.82	42.22 38.03	Water surface in dug well Water surface in well casing	8:00 a.m. 8:05 a.m.	
	Flow test with bucket Water samples taken			4.35 US Gallons/minute	8:10 a.m. 8:15 a.m.	4.25
	Flow test with bucket			3.76 US Gallons per minute	3:50 p.m.	3.76
		1.36 3.69	42.24 40.31	Water surface in dug well Water surface in well casing	4:00 p.m. 4:00 p.m.	
2024-08-17						
	Note: The hose was apparently crimped and stuck in the fence to hold it closed at some point between last evening's reading and this morning. Released just before I did my measurements today.					
		1.35 5.28	42.25 38.72	Water surface in dug well Water surface in well casing	8:50 a.m. 8:50 a.m.	
	Flow test with bucket Cleaned sand filter and opened valve to max No change in flow rate with two subsequent bucket tests			3.79 US Gallons/minute	9:00 a.m. 9:10 a.m. 9:15 a.m.	3.79
		1.36 3.90	42.24 40.10	Water surface in dug well Water surface in well casing	5:05 p.m. 5:05 p.m.	
	Flow test with bucket			3.53 US Gallons/minute	5:15 p.m.	3.53
2024-08-18						
	Note: Heavy prolonged rain the night before 17/18					
		1.37 6.64	42.23 37.36	Water surface in dug well Water surface in well casing	8:20 a.m. 8:20 a.m.	
	Flow test with bucket			3.62 US Gallons/minute	8:40 a.m.	3.62
		1.4 5.95	42.20 38.05	Water surface in dug well Water surface in well casing	3:15 p.m. 3:15 p.m.	
	Flow test with bucket			3.57 US Gallons/minute	3:25 p.m.	
2024-08-19						
		1.42 3.89	42.18 40.11	Water surface in dug well Water surface in well casing	8:35 a.m. 8:35 a.m.	
	Flow test with bucket			3.41 US Gallons/minute	8:45 a.m.	3.41
		1.43 5.6	42.17 38.40	Water surface in dug well Water surface in well casing	4:40 p.m. 4:40 p.m.	
	Flow test with bucket			3.70 US Gallons/minute	4:50 p.m.	3.7
2024-08-20						
		1.43 5.48	42.17 38.52	Water surface in dug well Water surface in well casing	7:50 a.m. 7:50 a.m.	
	Flow test with bucket			3.57 US Gallons/minute	8:00 a.m.	3.57
2024-08-21	No field monitoring					

Well Monitoring During August 2024 9-day Pumping Test

Date	Comments	Depth to Water (m)	Elev (m)	Comments	Time	Rate (USgpm)
2024-08-22	Flow test with bucket			3.53 US Gallons/minute	8:30 a.m.	3.53
2024-08-23	Flow test with bucket			3.23 US Gallons/minute	11:18 a.m.	3.23
	Flushed sand filter				11:20 a.m.	
	Flow test with bucket			3.50 US Gallons/minute	11:22 a.m.	
2024-08-24	Flow test with bucket			3.41 US Gallons/minute	11:35 a.m.	3.41
	Flushed sand filter				11:35 a.m.	
	Flow test with bucket			3.37 US Gallons/minute	11:39 a.m.	3.37
2024-08-25	Flow test with bucket			3.41 US Gallons/minute	11:40 a.m.	3.41
	Water temperature			12°C	11:42 a.m.	
	Water flow stopped				11:43 a.m.	
8/29/2024	Pulled data loggers				10:15 a.m.	

Pumping Summary

Pumping Cycle Activity

Recovery	8	mins
Pumping	3	mins
Total	11	mins

	USgpm	L/s
Min	3.2	0.20
Average	3.6	0.23
Median	3.5	0.22
Max	4.3	0.27
Number of readings =		13

In order to sustain a rate of 0.23 L/s over 8 minutes

the storage volume in the tank must be =	108.2	Litres
Pumping rate required to fill the pressure tank =	0.60	L/s
Rate for filling the tank and sustaining the flow =	0.83	L/s
	13.1	USgpm

Table IV

Step Test Run on Emcon Well Run on September 24th, 2024

Time	Depth to water (m)	Drawdown (m)	Rate (USgpm)	Rate (L/s)	Specific Capacity (L/s/m)	Notes
8:11						Pump turned off and system drained Initial reading at well 2.00 m to water Started pump at well head Step 1 - initial flow rate
8:27	2.00					
8:30						
8:30			4.0	0.25		
8:40	4.81	2.81			0.090	
8:50	4.92	2.92			0.086	
9:00						Increased flow for Step 2
9:04	6.85	4.85	9.0	0.6	0.117	
9:15	8.78	6.78			0.083	
9:27	9.27	7.27			0.078	
9:30						Increased flow for Step 3
9:32			13.8	0.9		
9:33	11.20	9.20			0.094	
9:42	12.49	10.49			0.083	
9:49	12.81	10.81			0.080	
10:00	13.07	11.07			0.078	
10:01			15.5	1.0		Increased flow for Step 4 The maximum that the pump could deliver
10:05	14.67	12.67			0.077	
10:12	16.33	14.33			0.068	
10:16	16.89	14.89			0.065	
10:25	17.67	15.67			0.062	
10:30	17.85	15.85			0.062	
10:31						Pump turned off Pump turned back on for works yard.
10:32	16.50	14.50				
10:37	8.52	6.52				
10:40	5.79	3.79				
10:42	5.08	3.08				
10:45	4.20	2.20				
10:52						

Notes:

- 1) See graph of water level trends and hydraulic analyses on Fig. 12.

Table V

Emcon Well (WTN 34154) Yield Assessment

Address	1400 Northwest Road	WTN 34154
WPN		14340
Depth from ground to (m)	SWL in summer	1.40
	First WB fracture	20.4
	Second WB fracture	27.7
	Bottom of well	32.6
Casing SU (m)		0.60
Elevation (m-asl)	Top of casing	44.0
	Ground	43.4
	SWL in summer	42.0
	Lowest during 5-day test	37.1
	Lowest during 9-day test	36.2
	Lowest during 2023 high rate test	35.2
	Lowest during 2024 Step test	28.2
	First WB fracture	23.0
	Second WB fracture	15.7
	Bottom of well	10.8
Drawdown	Maximum during 2023 5-day test	4.90
	Maximum during 2024 9-day test	5.80
	Average during 2023 5-day test	2.20
	Average during 2024 9-day test	3.00
	Maximum during 2023 high rate test	8.80
	Maximum during 2024 step test	15.85
	Conservative 100-day estimate at 0.25 L/s	4.2
	Available	21.6
	Design at long term yield rate (75%)	16.2
Pumping Rate (L/s)	3 minute maximum during 2023 5-day test	0.65
	3 minute maximum during 2024 9-day test	0.83
	Maximum during 2023 high rate test	0.00
	Maximum during 2024 step test	1.00
	Average during 2023 5-day test	0.18
	Average during 2024 9-day test	0.23
	Conservative estimate for long term yield	0.25
Pumping rate (USgpm)	Conservative estimate for long term yield	4.0
Duration (days)	Long term pumping	100
Specific Capacity (L/s/m)	Minimum during 2023 high rate test	0.060
	Minimum during 2024 step test	0.062
	Average during 2023 5-day test	0.08
	Average during 2024 9-day test	0.08
	Conservative estimate for 100 days	0.06

Notes:

- 1) See locations of well on Fig. 1
- 2) Well information based on well log presented on Fig. 3
- 3) Water level information is from graphs presented on Figs. 5 to 10 and Tables II, III and IV.

Table VI

Analysis of Capture Zone, Travel Time and Recharge Area

Capture Zone

Formula	Symbol	Parameter	Note No	Value	Unit
	Q	Estimated maximum long-term well yield	1	21,600	L/d
				0.25	L/s
				0.0003	m ³ /s
				3.3	lgpm
				4,770	gpd
	T	Transmissivity	2	3.0E-05	m ² /s
				2.6	m ² /d
	i	Gradient	3	0.05	
$Y = Q/2T/i$	Y	half width	4 & 5	83.3	m
	2Y	Width		166.7	m
$X = Y/\pi$	x	down distance	5	26.5	m

Estimated Length of Recharge Area

Width (see 2Y above)	166.7	m
Average annual precipitation	1,153.6	mm
	0.0032	m/day
Infiltration factor	0.2	
Infiltration	0.0006321	m/day
Well yield	21,600	L/d
	21.6	m ³ /d
Estimated length of capture zone required	205	m

Notes:

- 1) Assumes a constant pumping rate based on the average pumping rate from the 9-day pump test.
- 2) Transmissivity calculated from Leg 2 recovery from 9-day pump test (see Fig. 12)
- 3) Average gradient between Emcon well and estimate water table in Plateau area.
- 4) A short term 100% increase in pumping rate would increase width to 60m.
- 5) See dimension illustration below

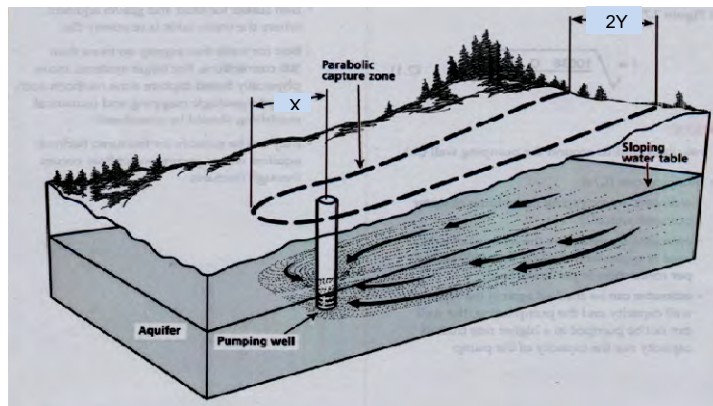


Table VII
Water Quality

Parameter	Well-->	34154					27383 On Property = 71.6m	MDL	Units	CDWQ Guideline	
		Emcon Well Depth = 32.8m								11-Jun-81	MAC
	Date -->	24-Jul-01	18-Dec-23	23-Dec-23	16-Aug-24	18-Aug-24					
Physical parameters											
pH		8.7	8.7	8.4		8.57	6.3	1	pH units		6.5-10.5
Colour True		5				< 5	-	5	Col Units		15
Specific Conductance (see Note 6)		925	540	951	741	1030	123	1	µS/cm		
Computed Conductance		1010	-	-		-	-		µS/cm		
Redox		-	115	121		-	-		mV		
Conductance % Difference		9.1				-	-		%		
Residue Nonfilterable (TSS)		<4			< 3	< 3	-	4	mg/L		
Residue Filterable 1.0µ (TDS)		488				564	-	10	mg/L		
Computed TDS		505				-	-		mg/L		
T5D % Diff		3.4				-	-		%		
Turbidity		0.64				0.29	-	10	NTU	1	5
Hardness Total		23.8				30.3	23.3		mg/L		
Absorbance UV (@245nm)						0.019			AU/cm		
Transmittance UV (@254nm)						95.7			%T/cm		
General Inorganics											
Alkalinity Phenolphthalein (as CaCO3)		10				-	< 0.5	1	mg/L		
Alkalinity Total (as CaCO3)		164				157	37	1	mg/L		
Carbonate (as CO3)		120				-	-		mg/L		
Bicarbonate (as HCO3-)		176				-	-		mg/L		
Hydroxide (as OH-)		<0.5				-	-	0.5	mg/L		
Anions											
Chloride		190				216	12.4	10	mg/L		250
Bromide		-				0.3			mg/L		
Fluoride		1.18				0.856	< 0.1	-	mg/L	1.5	
Ion Balance		4.5				-	-	-	%		
Total Anions		8.64				-	-	-	meq/L		
Total Cations		9.45				-	-	-	meq/L		
Langelier Index		0.4				-	-	-	pH units		
Saturation pH		8.3				-	-	-	pH units		

**Table VII
Water Quality**

Parameter	Well-->	34154					27383	MDL	Units	CDWQ Guideline	
		Emcon Well Depth = 32.8m					On Property = 71.6m			MAC	AO
		Date -->	24-Jul-01	18-Dec-23	23-Dec-23	16-Aug-24					
Nitrogen											
Ammonia (N)		0.005				0.137	-		mg/L		
Nitrate-Nitrogen (Dissolved)		<0.02				-	-	-	mg/L	10	
Nitrate+Nitrite (N)		<0.02				-	< 0.02	0.02	mg/L	10	
Nitrate (N) Total		<0.005				<0.025	-	0.005	mg/L	10	
Nitrite (N)		-				<0.005	-	0.001	mg/L		
Nitrogen TKN		-				0.213	0.07		mg/L		
Nitrogen Total						-	0.07		mg/L		
Phosphorus											
Ortho-phosphorus		0.038				-	-	0.005	mg/L		
Phosphorus-Total		0.077				<0.050	< 0.003	0.005	mg/L		
Sulphur											
Sulphide Total (as S)		-				0.379	-		mg/L		
Sulphide Total (as H ₂ S)		-				0.403	-		mg/L		
Sulphate		<1.0				< 1.5	< 5	1.0	mg/L		500
Organics											
Tannin and lignin (as tannic acid)						< 0.1					
Metals											
Aluminum		0.003				0.0181	-	0.02	mg/L		
Antimony		-				<0.00010	-		mg/L		
Arsenic		<0.001				<0.00010	-	0.001	mg/L	0.01	
Barium		0.305				0.455	-	0.001	mg/L		1.0
Barium		-				<0.00010	-		mg/L		
Beryllium		-				<0.00005	-		mg/L		
Boron		0.841				0.652	-	0.008	mg/L	5.0	
Cadmium		<0.002				<0.000005	-	0.002	mg/L	0.005	
Calcium		9.07				11.6	6.2	0.05	mg/L		
Cesium		-				0.000035	-		mg/L		
Chromium		<0.002				<0.0005	-	0.002	mg/L	0.05	
Cobalt		<0.003				<0.00010	-	0.003	mg/L		
Copper		0.002				<0.0005	-	0.001	mg/L		1
Iron		0.036				<0.010	1.2	0.005	mg/L		0.3
Lead		<0.001				<0.00005	-	0.001	mg/L		

**Table VII
Water Quality**

Parameter	Well-->	34154					27383	MDL	Units	CDWQ Guideline	
		Emcon Well Depth = 32.8m					On Property = 71.6m			MAC	AO
	Date -->	24-Jul-01	18-Dec-23	23-Dec-23	16-Aug-24	18-Aug-24	11-Jun-81				
Lithium		-				0.0254	-		mg/L		
Magnesium		0.28				0.329	1.9	0.05	mg/L		
Manganese		0.009				0.00897	0.05	0.001	mg/L	0.12	0.02
Mercury		-				<0.000005	-		mg/L		
Molybdenum		<0.005				<0.00005	-	0.005	mg/L		
Nickel		<0.008				<0.0005	-	0.008	mg/L		
Potassium		<0.4				0.281	0.2	0.4	mg/L		
Rubidium		-				0.00029	-		mg/L		
Selenium		<0.001				<0.00005	-	0.001	mg/L	0.01	
Silicon		-				4.08	17.0		mg/L		
Silver		<0.01				<0.00001	-	0.01	mg/L		
Sodium		206			144	173	15.6	0.05	mg/L		200
Strontium		-				0.564	-		mg/L		
Sulfur		-				<0.50	-		mg/L		
Tellurium		-				<0.00020	-		mg/L		
Thallium		-				<0.000010	-		mg/L		
Thorium		-				<0.00010	-		mg/L		
Tin		-				<0.00010	-		mg/L		
Titanium		-				0.00057	-		mg/L		
Tungsten		-				0.00039	-		mg/L		
Uranium		-				<0.000010	-		mg/L		
Vanadium		0.003				<0.00050	-	0.003	mg/L		
Zinc		0.051				<0.0030	-	0.002	mg/L		5.0
Zirconium						<0.00020	-		mg/L		
Microbiological											
Coliform-Total		PRESENT				272	-		CFU/100	0	
Coliform-Fecal		ABSENT				-	-		CFU/100	0	
Coliform-Escherichia (E-coli)		-				1	-		CFU/100		
Bacteria iron related (estimate)		-				35,000	-		CF units		
Bacteria - sulphate reducing (estimate)		-				325	-		CF units		
Heterotrophic Plate Count (HPC)		-				>5,700	-		CF units		
Dominant bacteria (See Note 5)		-					-				

**Table VII
Water Quality**

Parameter	Well-->	34154					27383 On Property = 71.6m	MDL	Units	CDWQ Guideline	
		Emcon Well Depth = 32.8m								11-Jun-81	MAC
	Date -->	24-Jul-01	18-Dec-23	23-Dec-23	16-Aug-24	18-Aug-24					
Hydrocarbons							.				
VH C6-C10		<0.1			-	-	0.1	mg/L			
VPW		<0.1			-	-	0.1	mg/L			
Volatile Organics-MAH							°				
Benzene		<0.5			-	-	5	ug/L	5		
Ethyl benzene		<0.5			-	-	0.5	ug/L		2.4	
Toluene		<0.5			-	-	0.5	ug/L		524	
Xylem-Total		<0.5			-	-	0.5	ug/L		300	

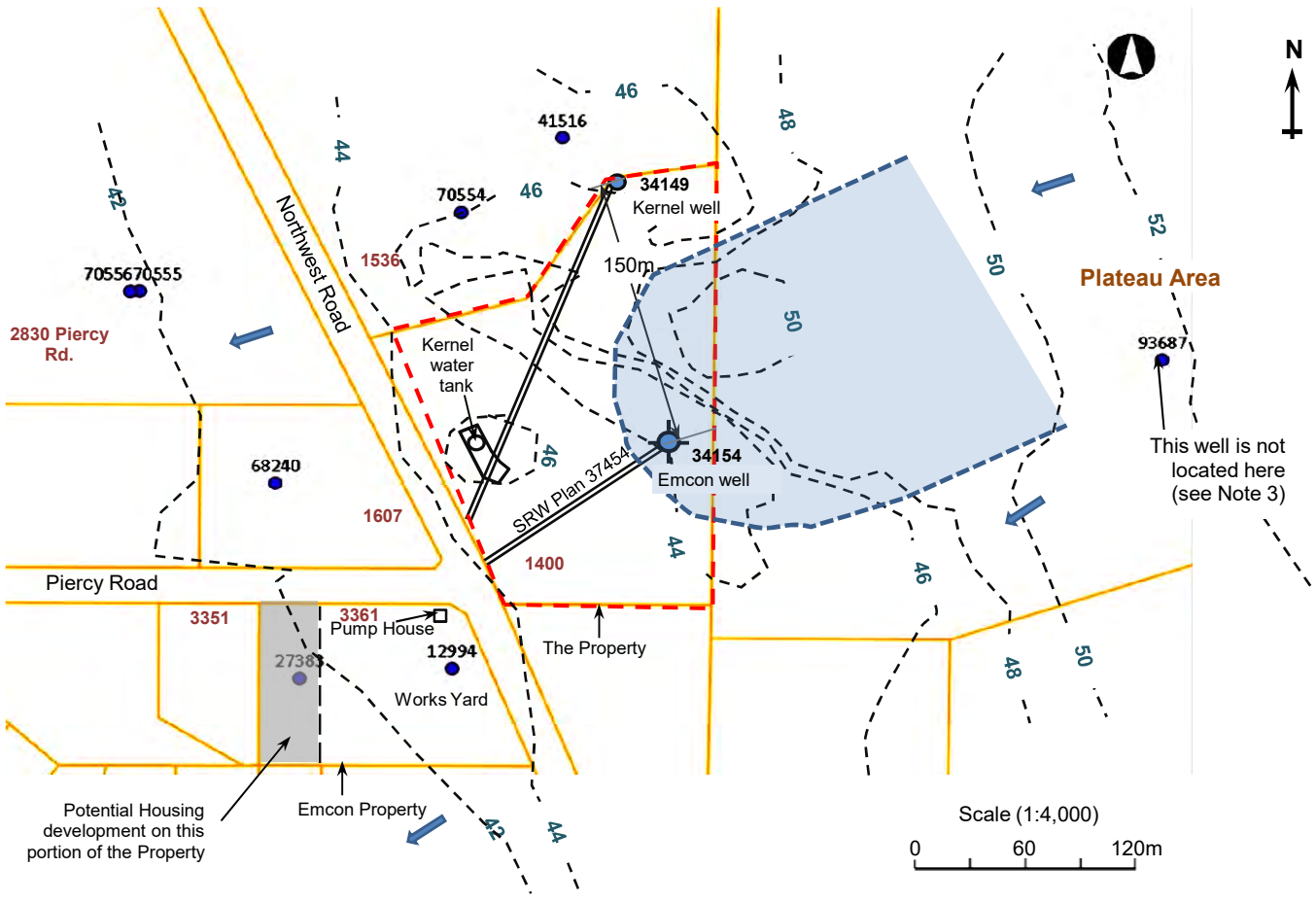
Notes

- 1) See locations of wells on Fig. 1
- 2) CDWQ = Canadian Drinking Water Quality
- 3) MDL = minimum detection limit for the laboratory analysis used for Well 34154 well water analysis.
- 4) Bolded and underlined **red** values exceed the MAC and Bolded and underlined **values** exceed the AO limit.
- 5) Dominant bacteria include pseudomonades a combination of aerobic and anaerobic SRB
- 6) The EC in a water sample collected at the end of the 9-day pumping test on August 25th was 1092 $\mu\text{S}/\text{cm}$.

MAC= Maximum acceptable concentration

AO = Aesthetic Objective

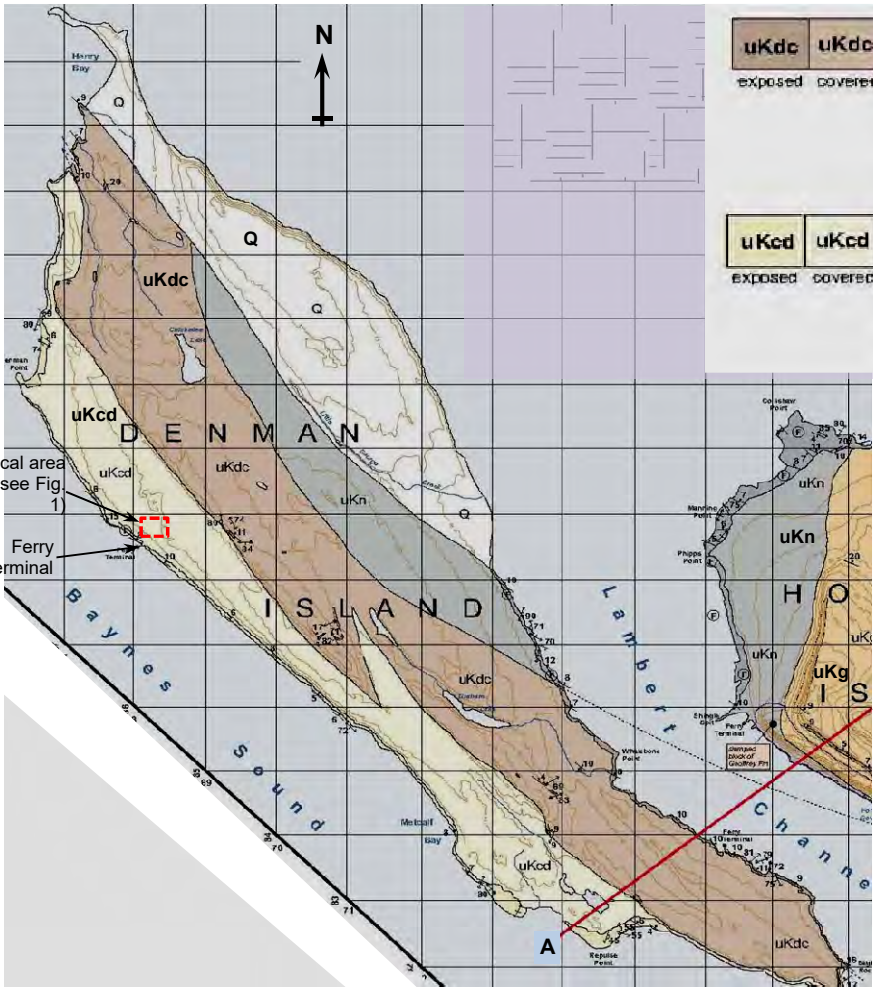
Figures



- Legend**
- Well site legal right-of-way.
 - 73591 Water well from MOE wells Database with indicated well tag number.
 - The Emcon pump tested well
 - Topographic contour 2m interval (m-asl)
 - Interpreted groundwater flow direction
 - Estimated extent of well capture zone when pumping at 0.23 L/s.

- NOTES**
- 1) Base map with well locations modified from Province of BC G-wells web mapping.
 - 2) See information on wells listed on Table I.
 - 3) The information on well 93687 matches that of the Kernel well (34149) and it is assumed that no well is present at the location indicated for well 93687.

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<p>Assessment of Sustainable Yield and Potential Impacts from use of Emcon Services Inc. Well on 1400 Northwest Road Property Easement, Denman Island, B.C.</p>	<p>Well Location Map.</p>	<p>Drawn: rad</p>	<p>Date Oct. 2024</p>
<p>Approved: </p>		<p>Fig. 1</p>	



uKdc **uKdc**
exposed covered

DE COURCY FORMATION: Massive, light-olive grey, medium- to coarse-grained, poorly sorted, thick-bedded sandstone (feldspathic litharenite) containing 45-50% rock fragments including 15% chert. Sandstone is interbedded with thick-bedded, channelized, clast-supported pebble-cobble conglomerate containing a high proportion of mafic and felsic extrusive clasts.

uKcd **uKcd**
exposed covered

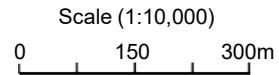
CEDAR DISTRICT FORMATION: Massive, dark grey mudstone containing abundant calcium carbonate concretions. Mudstone is locally interbedded and interbedded with siltstone and fine-grained, thin-bedded parallel- and current-ripple-laminated sandstone. Common clastic dikes and slump folded layers

Q

QUATERNARY DEPOSITS: Sand and gravel.

[Red dashed box symbol]

Area around the Property (see Note 2)

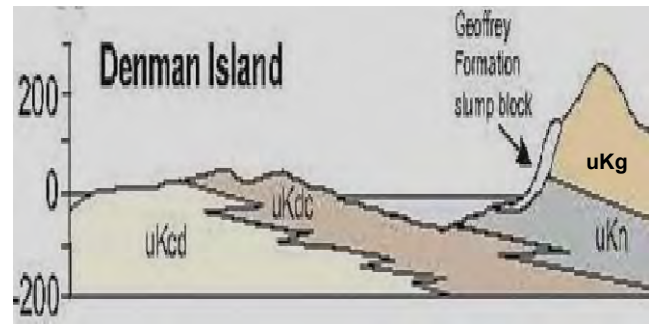


uKg **uKg**
exposed covered

GEOFFREY FORMATION: Thick-bedded, channelized, clast-supported pebble-cobble conglomerate containing predominantly mafic and felsic extrusives and mafic intrusive clasts; in a matrix of medium-grained, light olive grey sandstone. Conglomerate is interbedded with medium- to coarse-grained, light olive grey, massive, parallel and current ripple laminated, thick-bedded sandstone (feldspathic litharenite); minor mudstone.

uKn **uKn**
exposed covered

NORTHUMBERLAND FORMATION: Massive, dark grey mudstone containing abundant calcium carbonate concretions. Mudstone is locally interbedded and interbedded with siltstone and fine-grained, parallel and current ripple laminated sandstone. Common clastic dikes and slump folded layers.



Section A-A'

- NOTES**
- 1) Map from Katnick D.C. and Mustard P.S. 2001. Geoscience Map 2001-3 50,000 scale map prepared for BC Geological Survey Branch.
 - 2) See detailed local area map on Fig. 1

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Assessment of Sustainable Yield and Potential Impacts from use of Emcon Services Inc. Well on 1400 Northwest Road	Geology and Location Map.	Drawn: rad	Date Oct. 2024
		Approved: 	Fig. 2

JOB NUMBER : 308

Borehole No: **Emcon Well (WTN 34154)**
 Date Drilled: 1976 WPN = 14340
 Method: Cable tool
 Datum above ground (m): 0.6
 Elevation top of flange (m-asl): 44.0

Constructed By: Unknown
 Hole Diameter: 150 mm
 Ground elevation: 43.4 m-asl
 Depth to water at construction : na m-btoc
 December 18, 2024 depth to water: 0.85 m-bg

Depth (m)	Elevation (m)	Description of lithology encountered	Well Construction Materials	Well Diagram
0.0	43.4	Ground Surface		
4.6	38.8	Overburden - type is not specified (assumed to be sandy loam and possibly with some organic soil.)	SWL Aug. 16, 2024 150mm diam steel casing	
10.0	33.4	Shale bedrock	Lowest water level during 5-day test Lowest water level during 9-day test	
20.0	23.4	Water bearing fracture yielding 0.25 L/s (4 USgpm)	Lowest level during September 2024 step test	
20.4	20.4	Shale bedrock		20.4 xxx El. 23.4
27.7	15.7	Water bearing fracture yielding 0.13 L/s (2 USgpm)	150mm diam unlined borehole	27.7 xxx El. 15.7
30.0	13.4	Sandstone bedrock		
32.6	10.8	Shale bedrock	Bottom of well	El. 10.8

Notes:
 1) There is no indication on the well log that a surface seal was installed.
 2) Top of casing elevation based on 2m interval topographic contour map (see Fig. 1).

Notation:
 m-btoc = metres below top of steel casing.
 m-bg = metres below ground.

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Assessment of Sustainable Yield and Potential Impacts from use of Emcon Services Inc. Well on 1400 Northwest Road Property Easement, Denman Island, B.C.	BY: rad	DATE: Oct. 2024
	APPROVED:	Fig. 3

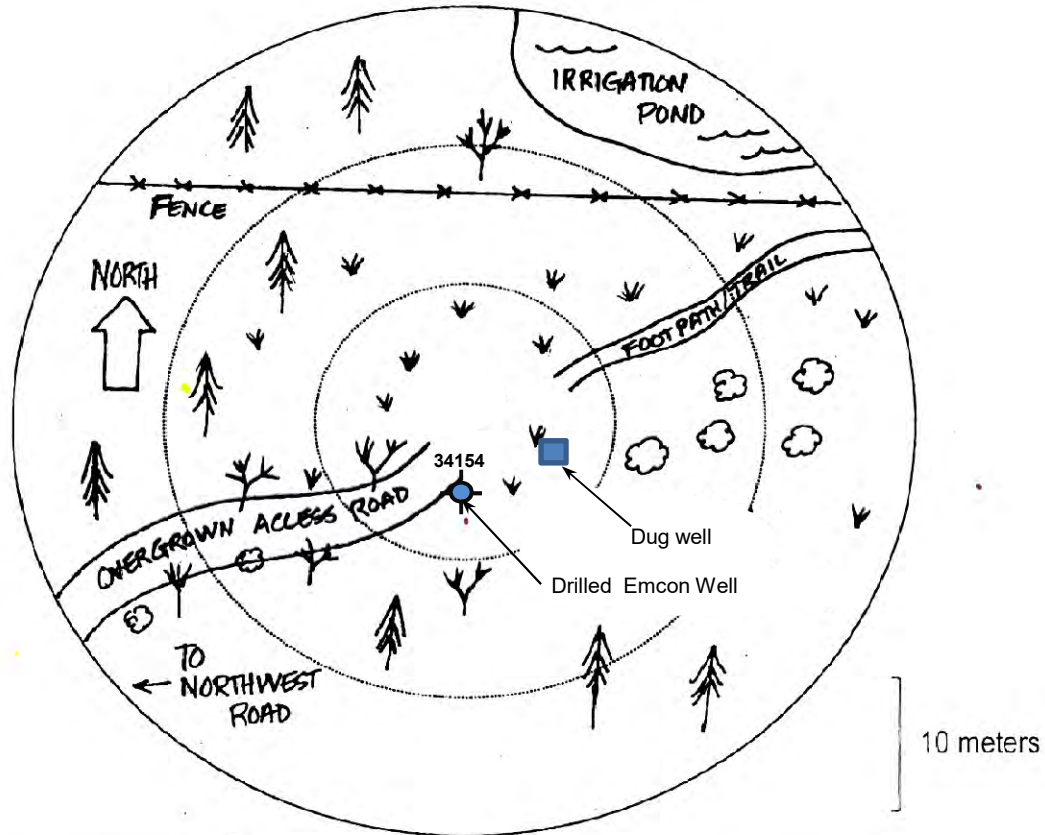

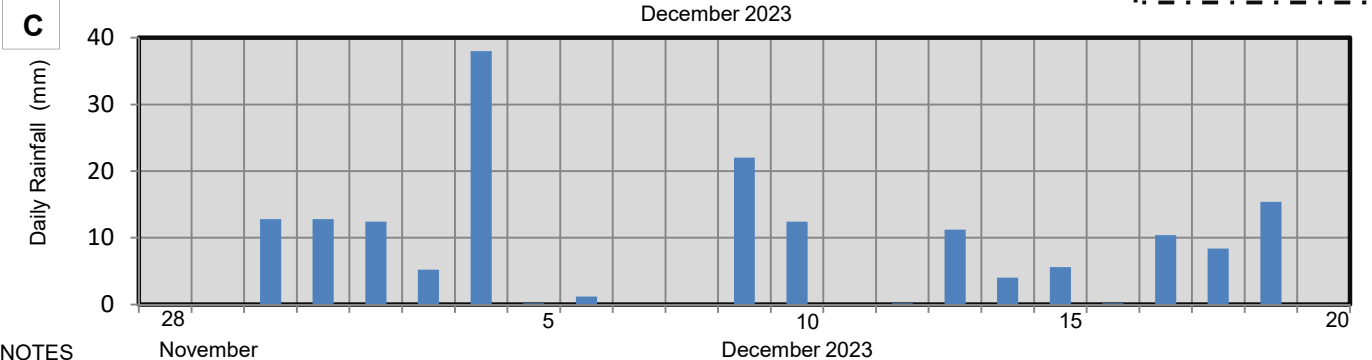
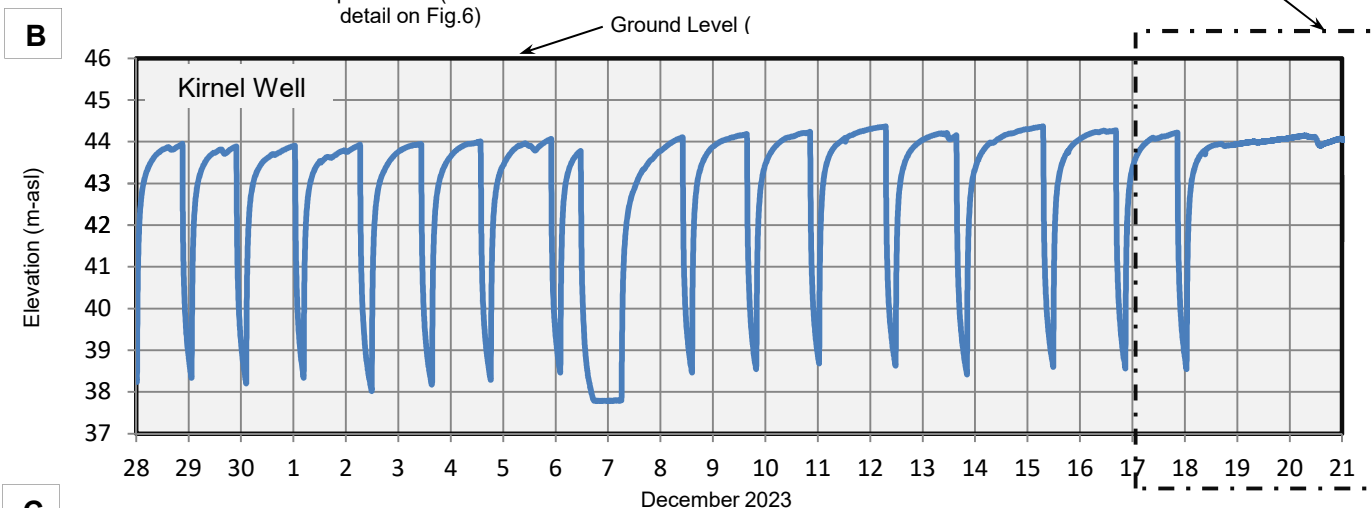
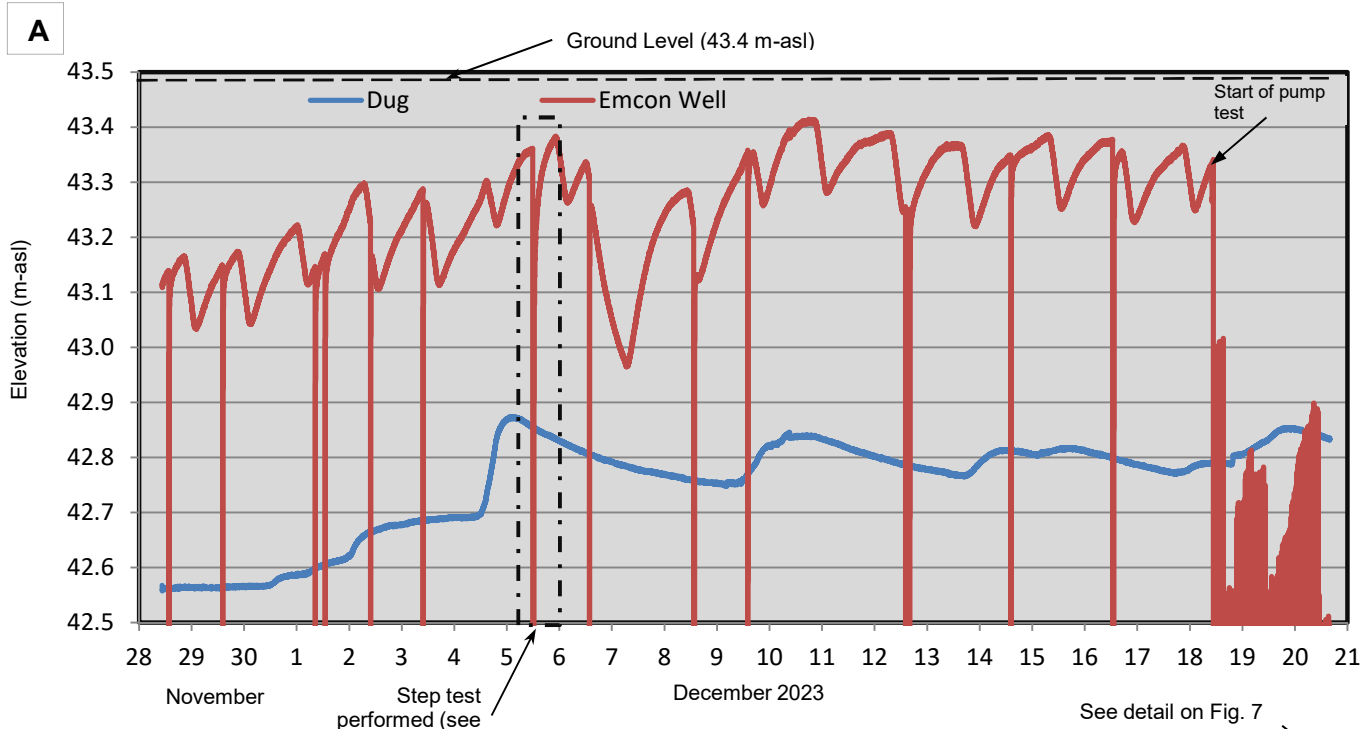


Diagram of sanitary area (30 meter radius) around the well

NOTES

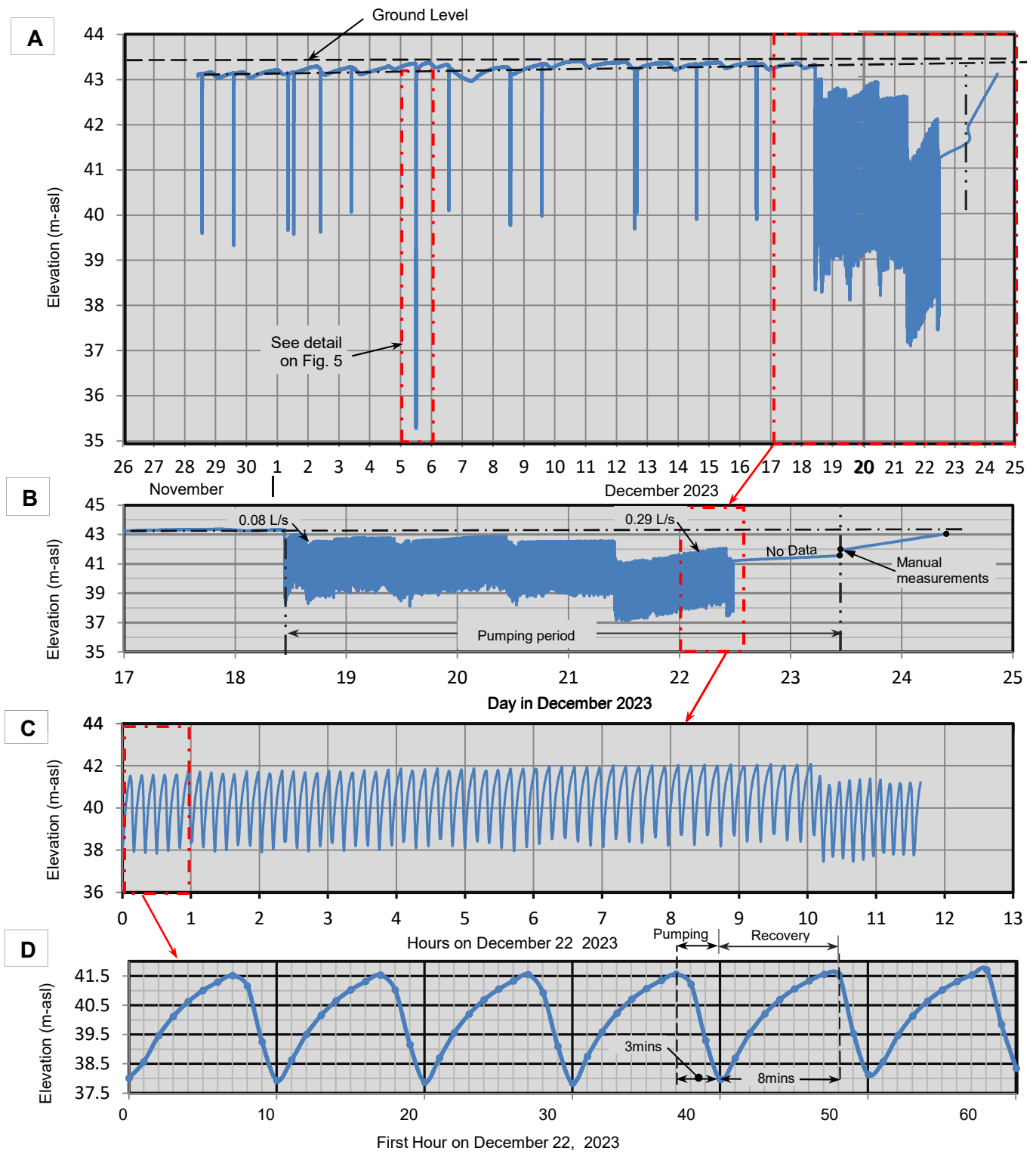
- 1) Sketch modified from Figure 1 in Kenny, S. 2001.

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<p>Assessment of Sustainable Yield and Potential Impacts from use of Emcon Services Inc. Well on 1400 Northwest Road Property Easement, Denman Island, B.C.</p>	<p>Sketch of Well Site</p>	<p>Drawn: rad</p>	<p>Date Oct. 2024</p>
		<p>Approved: </p>	<p>Fig. 4</p>



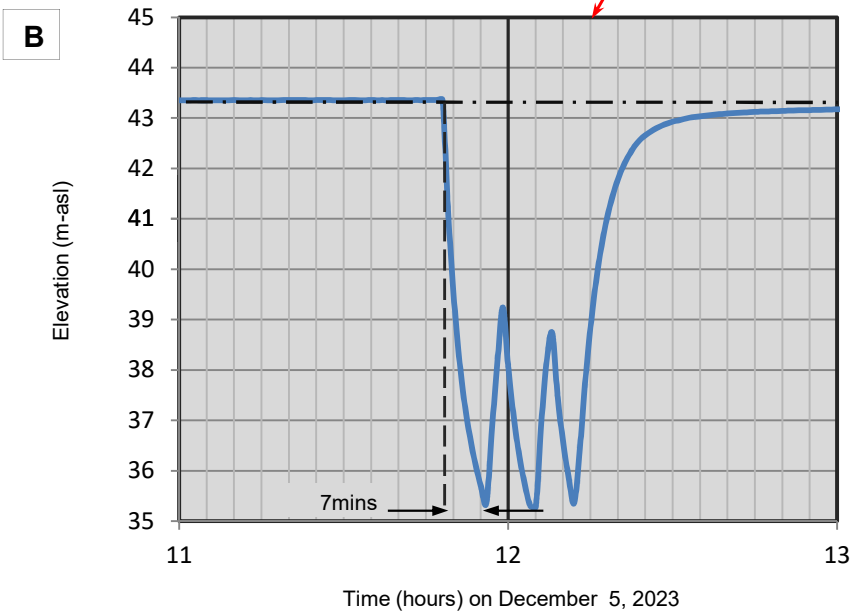
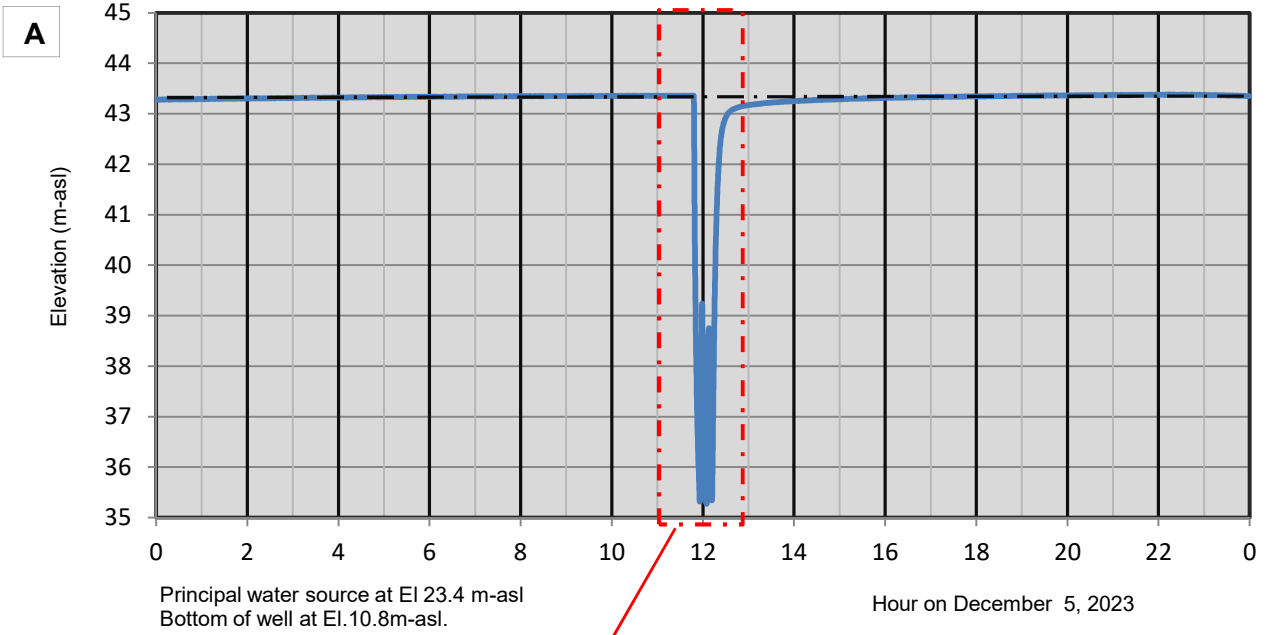
- NOTES
- 1) See location of wells on Figs 1 and 4.
 - 2) Rainfall data from Comox Airport Station.

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<p>Assessment of Sustainable Yield and Potential Impacts from use of Emcon Services Inc. Well on 1400 Northwest Road Property Easement, Denman Island, B.C.</p>	<p>Water Levels in Emcon and Kirnel Drilled Wells and in Emcon Dug Well</p>	<table border="1"> <tr> <td>Drawn: rad</td> <td>Date Oct. 2024</td> </tr> <tr> <td>Approved: </td> <td>Fig. 5</td> </tr> </table>	Drawn: rad	Date Oct. 2024	Approved: 	Fig. 5
Drawn: rad	Date Oct. 2024					
Approved: 	Fig. 5					



NOTES
 1) See location of well on Figs.1 and 4.

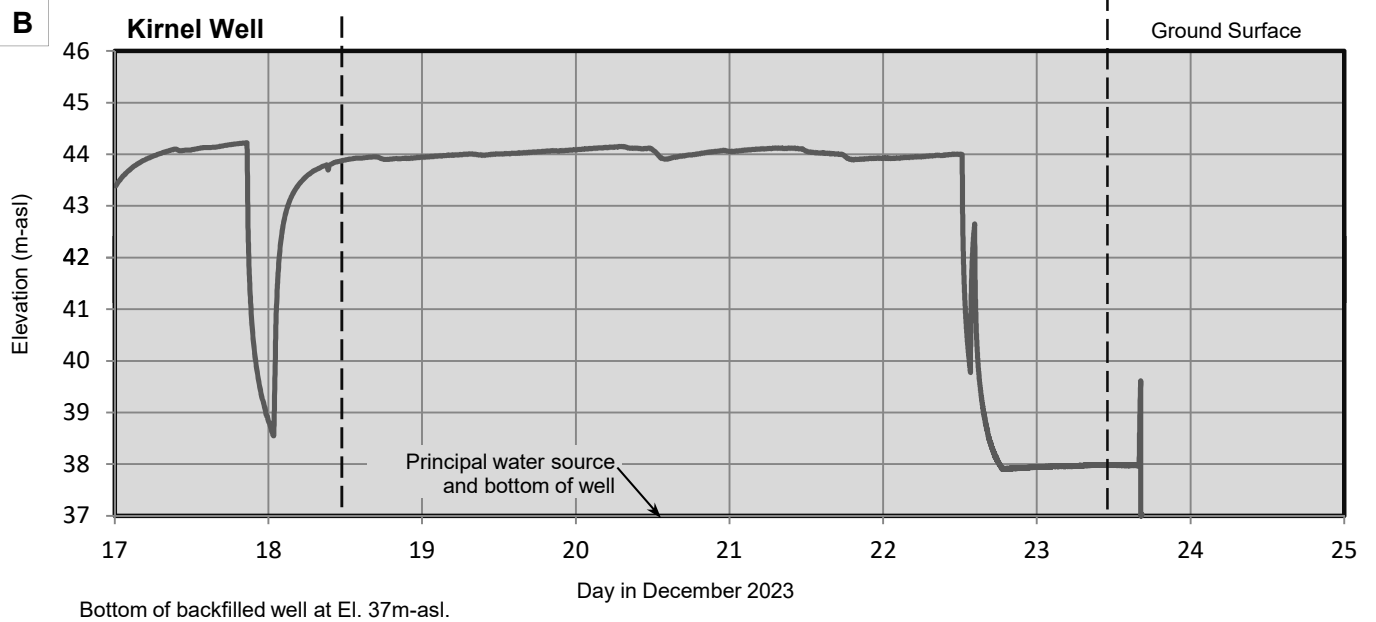
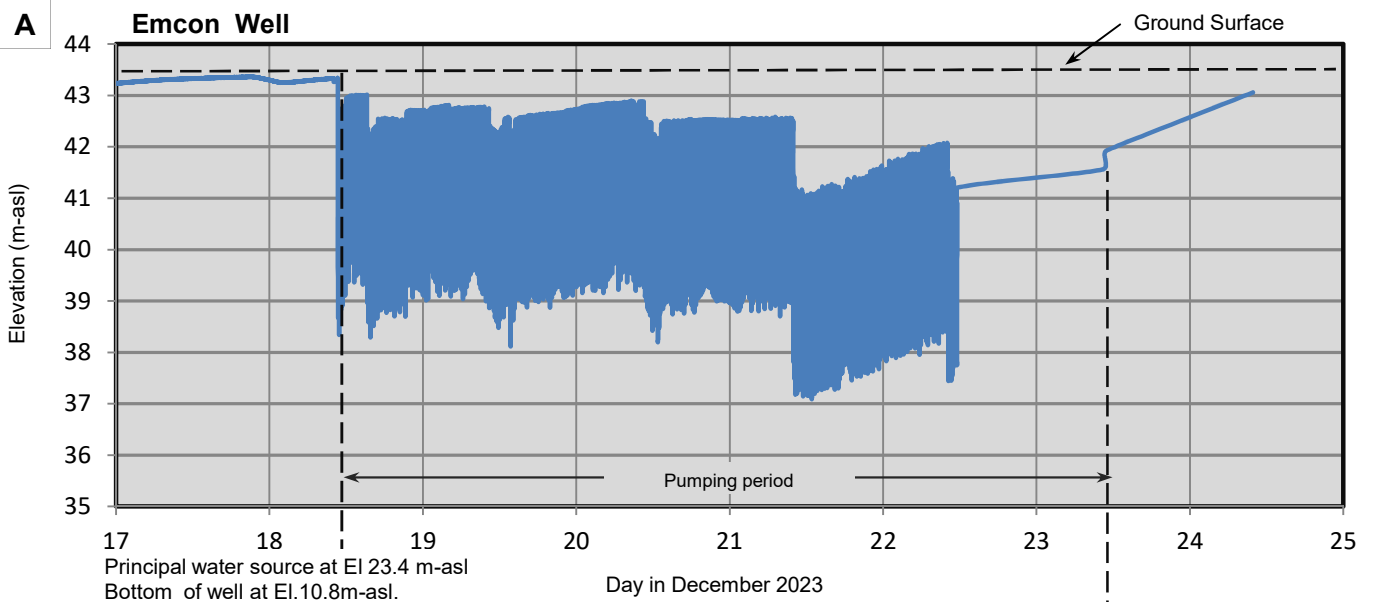
<p>Denman Community Housing Society</p>	<p>ELANCO ENTERPRISES LTD. Victoria, B.C. (250 744-1357) Permit to Practice No: 1001505</p>					
<p>Assessment of Sustainable Yield and Potential Impacts from use of Emcon Services Inc. Well on 1400 Northwest Road Property Easement, Denman Island, B.C.</p>	<p>Elevation of Water levels in Well 34154 (Emcon Well)</p>	<table border="1"> <tr> <td>Drawn: rad</td> <td>Date Oct. 2024</td> </tr> <tr> <td>Approved: </td> <td>Fig. 6</td> </tr> </table>	Drawn: rad	Date Oct. 2024	Approved: 	Fig. 6
Drawn: rad	Date Oct. 2024					
Approved: 	Fig. 6					



Pumping rate (L/s) = 0.5 L/s
 Drawdown (m) = 8 m
 Specific capacity (L/s/m) = 0.06 L/s/m

NOTES
 1) See location of well on Fig.1

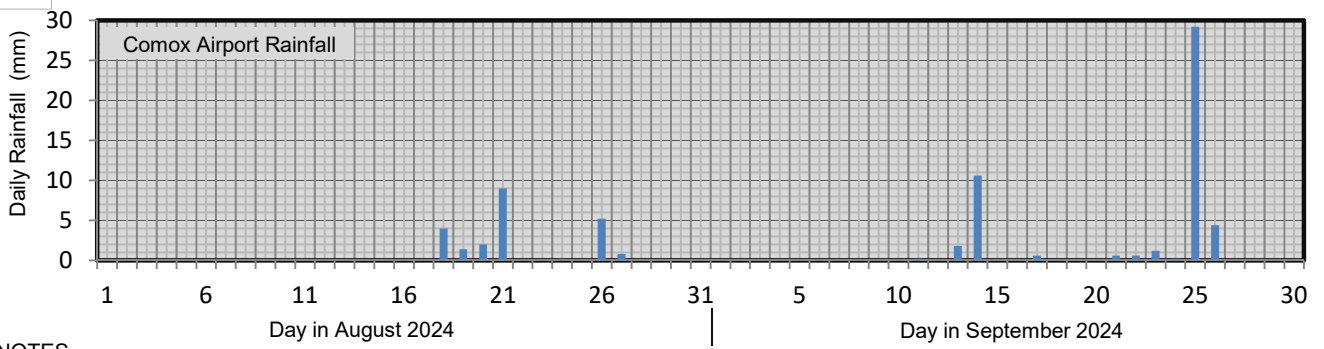
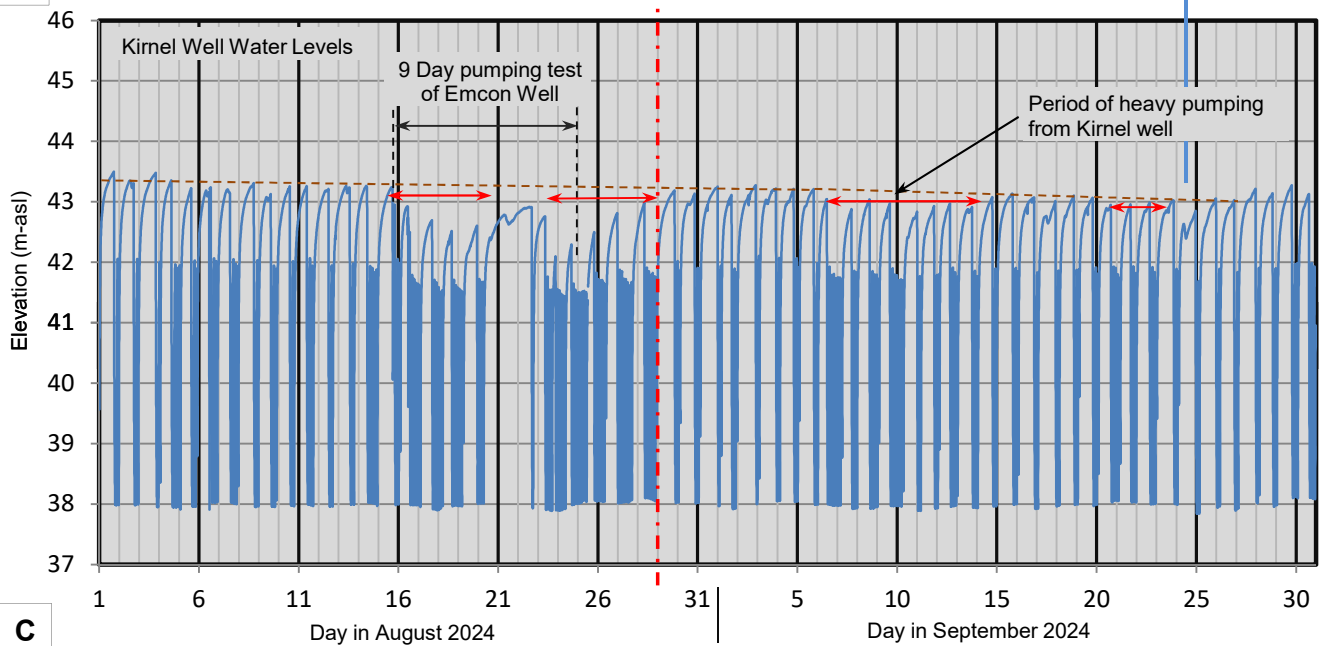
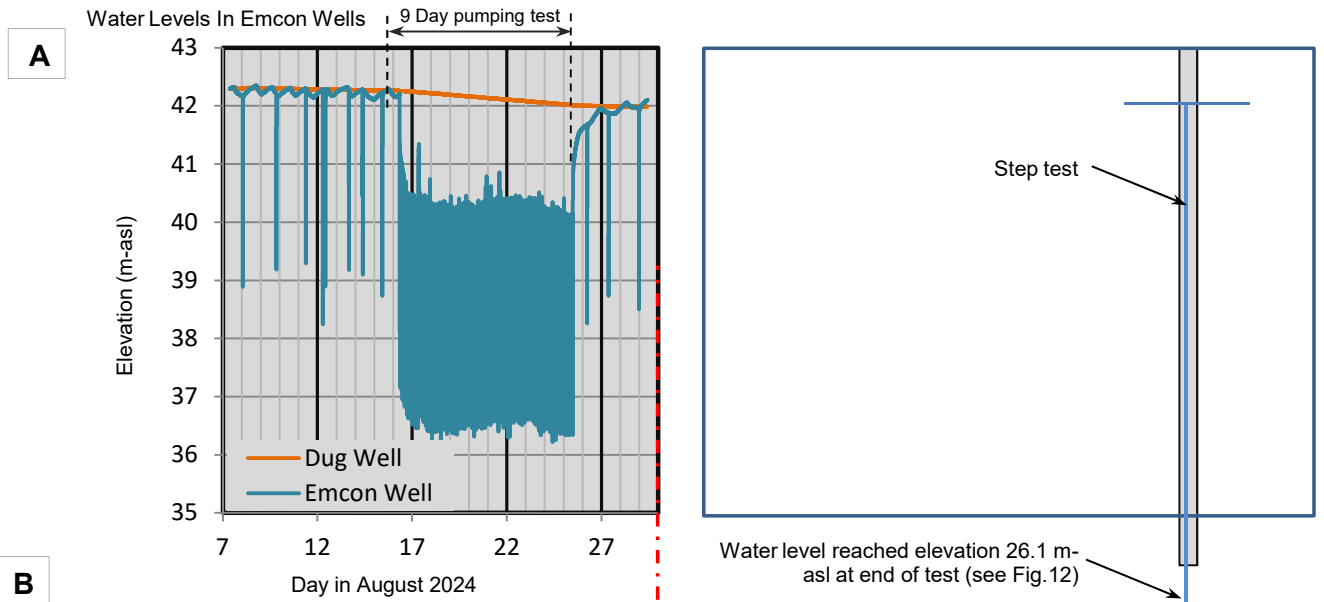
<p>Denman Community Housing Society</p>	<p>ELANCO ENTERPRISES LTD. Victoria, B.C. (250 744-1357) Permit to Practice No: 1001505</p>					
<p>Assessment of Sustainable Yield and Potential Impacts from use of Emcon Services Inc. Well on 1400 Northwest Road Property Easement, Denman Island, B.C.</p>	<p>Detail of December 5, 2023 Brief Pump Test in Emcon Well</p>	<table border="1"> <tr> <td>Drawn: rad</td> <td>Date Oct. 2024</td> </tr> <tr> <td>Approved: </td> <td>Fig. 7</td> </tr> </table>	Drawn: rad	Date Oct. 2024	Approved: 	Fig. 7
Drawn: rad	Date Oct. 2024					
Approved: 	Fig. 7					



NOTES

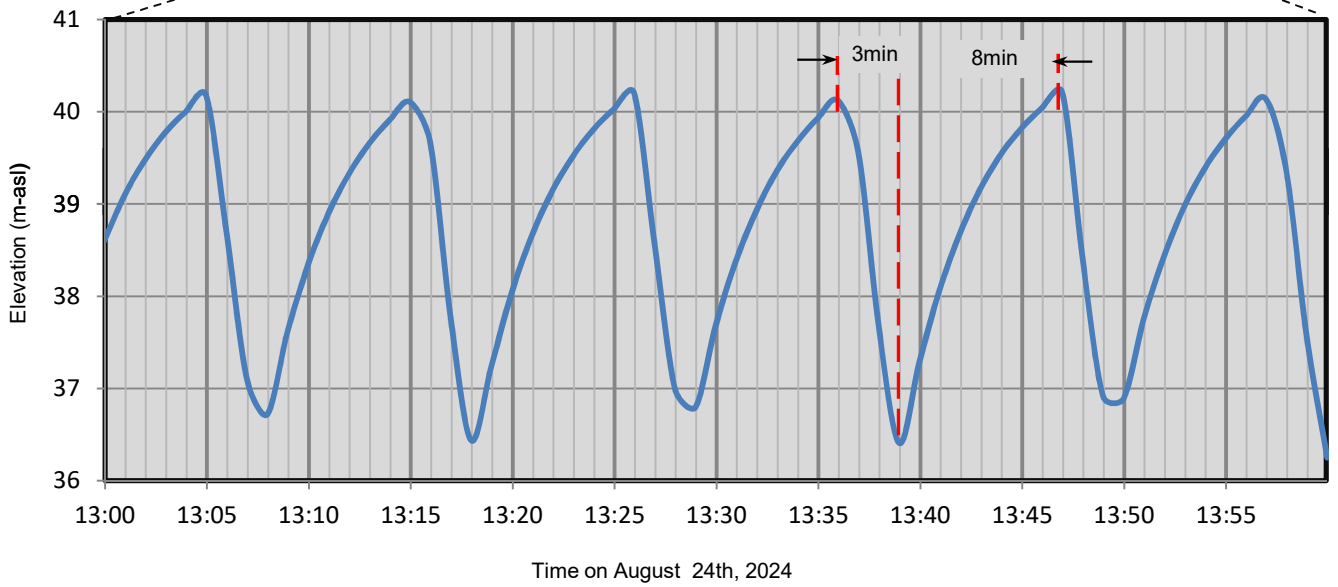
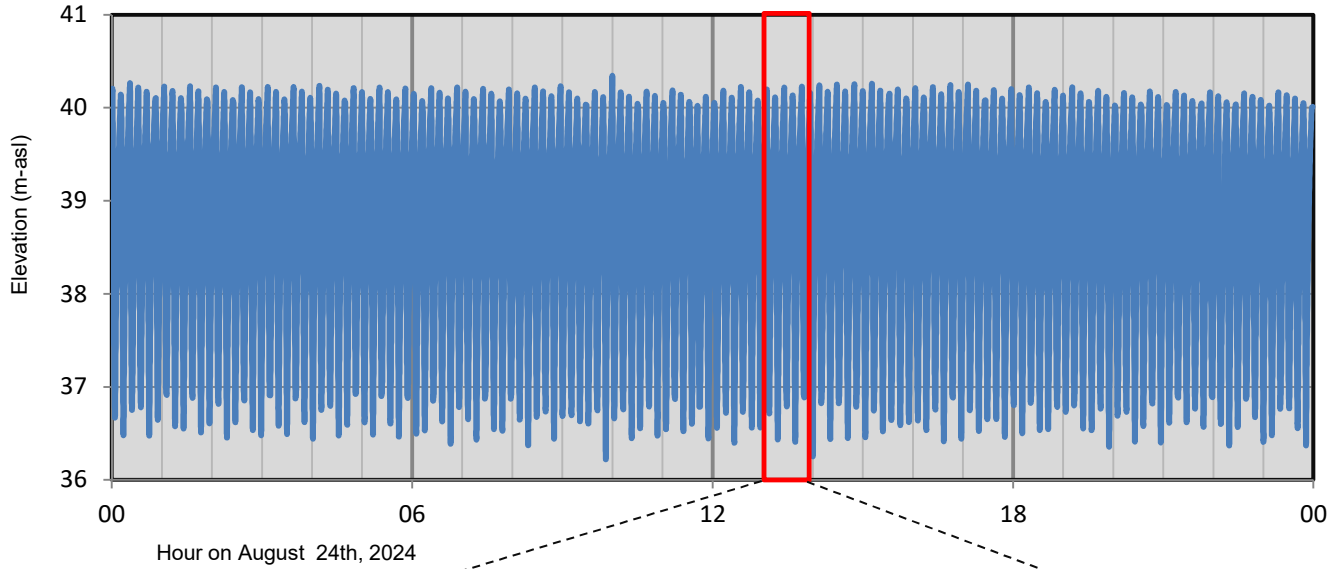
1) See locations of wells on Fig.1.

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<p>Assessment of Sustainable Yield and Potential Impacts from use of Emcon Services Inc. Well on 1400 Northwest Road Property Easement, Denman Island, B.C.</p>	<p>Comparison Between Water Levels in Wells During 5-Day Emcon Pumping Period</p>	<table border="1"> <tr> <td>Drawn: rad</td> <td>Date Oct. 2024</td> </tr> <tr> <td>Approved: </td> <td>Fig. 8</td> </tr> </table>	Drawn: rad	Date Oct. 2024	Approved: 	Fig. 8
Drawn: rad	Date Oct. 2024					
Approved: 	Fig. 8					



NOTES
 1) Water levels in Emcon Well was recorded at 1-minute intervals and in Kernel well at 10-minute intervals.

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<p>Assessment of Sustainable Yield and Potential Impacts from use of Emcon Services Inc. Well on 1400 Northwest Road Property Easement, Denman Island, B.C.</p>	<p>Water Level Elevations in Wells and Daily Rainfall.</p>	<table border="1"> <tr> <td>Drawn: rad</td> <td>Date Oct. 2024</td> </tr> <tr> <td>Approved: </td> <td>Fig. 9</td> </tr> </table>	Drawn: rad	Date Oct. 2024	Approved: 	Fig. 9
Drawn: rad	Date Oct. 2024					
Approved: 	Fig. 9					



NOTES

- 1) See locations of well on Fig.1.
- 2) See long term water level trends on Fig. 9


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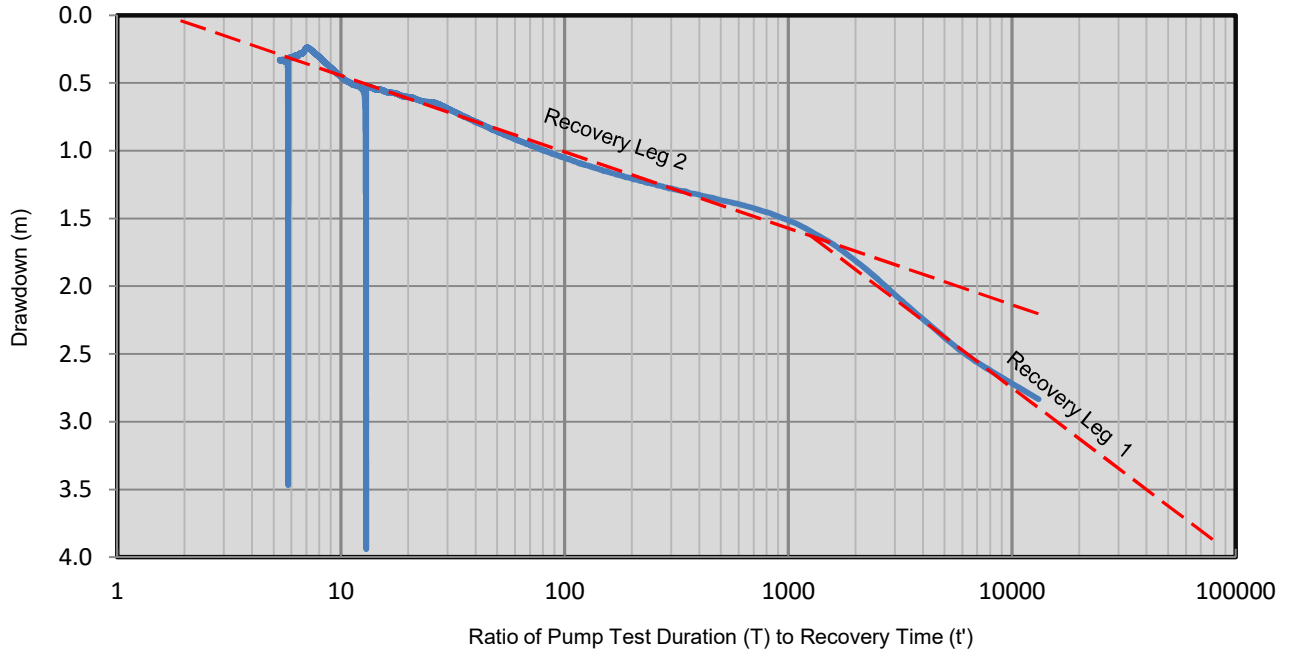
Assessment of Sustainable Yield and Potential Impacts from use of Emcon Services Inc. Well on 1400 Northwest Road Property Easement, Denman Island, B.C.

Detail of Emcon Water Level Fluctuations on August 24, 2024

Drawn: rad Date Oct. 2024

Approved:  Fig. **10**

A



Estimates for fracture zone transmissivity
 $Transmissivity = 1.83 * 10^{-4} * Q / \Delta S$

	Q (L/s)	ΔS (m)	T (m ² /s)
Recovery (Leg 1)	0.23	5	8.4E-06
Recovery (Leg 2)	0.23	1.3	3.2E-05

NOTES

1) See well location on Fig. 1

Denman Community Housing Society

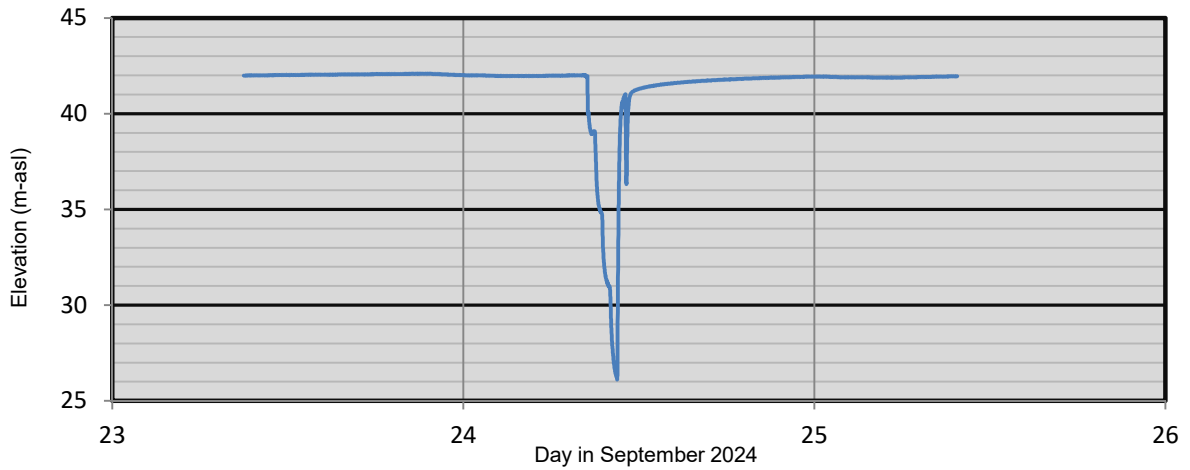
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Assessment of Sustainable Yield and Potential Impacts from use of Emcon Services Inc. Well on 1400 Northwest Road Property Easement, Denman Island , B.C.

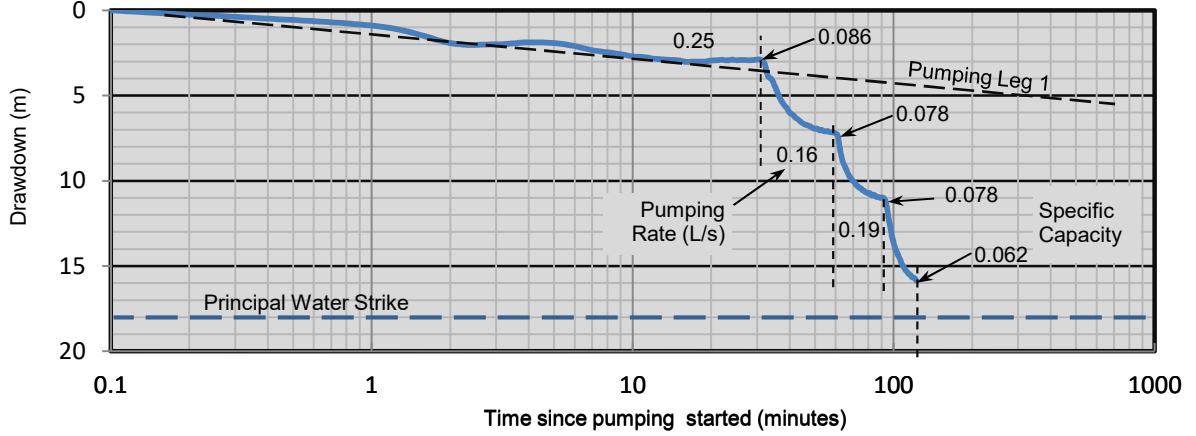
Semi-log Graph of Water Level Recovery in Emcon Well Following 9-Day Test.

Drawn: rad	Date Oct. 2024
Approved: 	Fig. 11

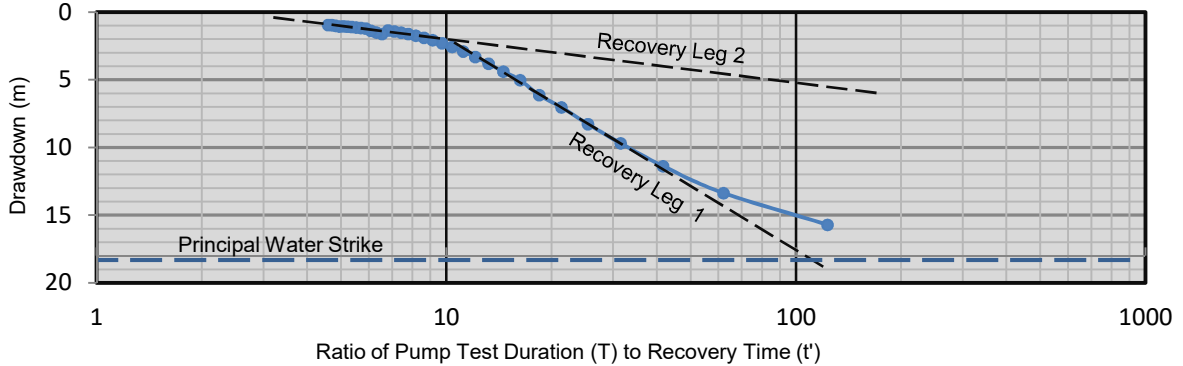
A



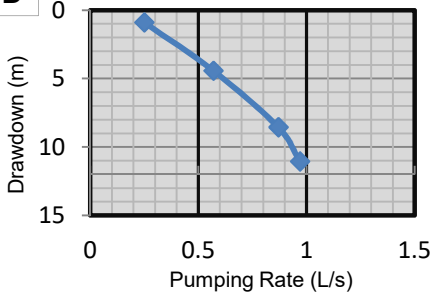
B



C



D



Estimates for fracture zone transmissivity
 $Transmissivity = 1.83 * 10^{-4} * Q / \Delta S$

	Q (L/s)	ΔS (m)	T (m ² /s)
Pumping Leg 1	0.25	3.0	1.5E-05
Recovery (Leg 1)	0.64	14	8.4E-06
Recovery (Leg 2)	0.64	3	3.9E-05


Notes:
 1) See details on Table IV
 2) See well location on Fig. 1

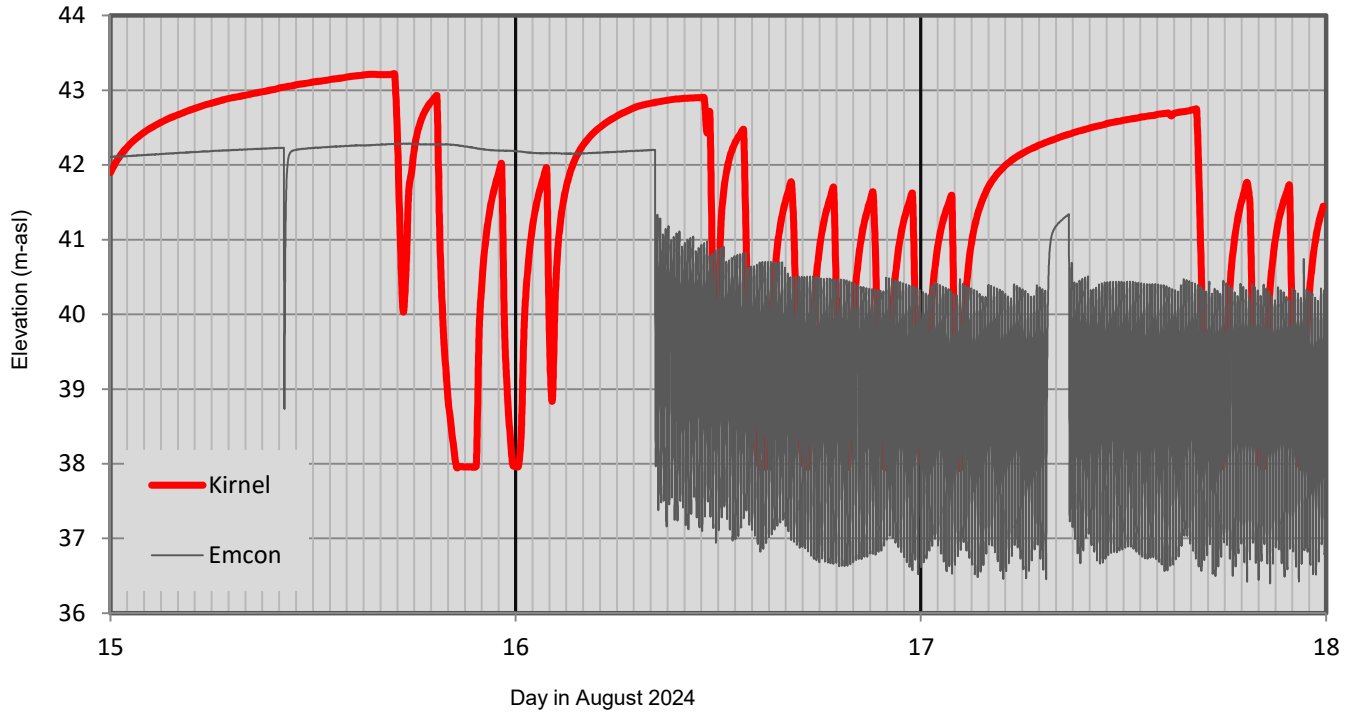
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Assessment of Sustainable Yield and Potential Impacts from use of Emcon Services Inc. Well on 1400 Northwest Road Property Easement, Denman Island, B.C.

Step Test Water Level Trends

Drawn: rad
 Date: Oct. 2024
 Approved: 
 Fig. **12**



NOTES

1) See well location on Fig. 1

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Assessment of Sustainable Yield and Potential Impacts from use of Emcon Services Inc. Well on 1400 Northwest Road Property Easement, Denman Island, B.C.

Comparison Between Emcon and Kirnel Well Water Levels at Start of 9-Day Pump Test

Drawn: rad	Date Oct. 2024
Approved: 	Fig. 13