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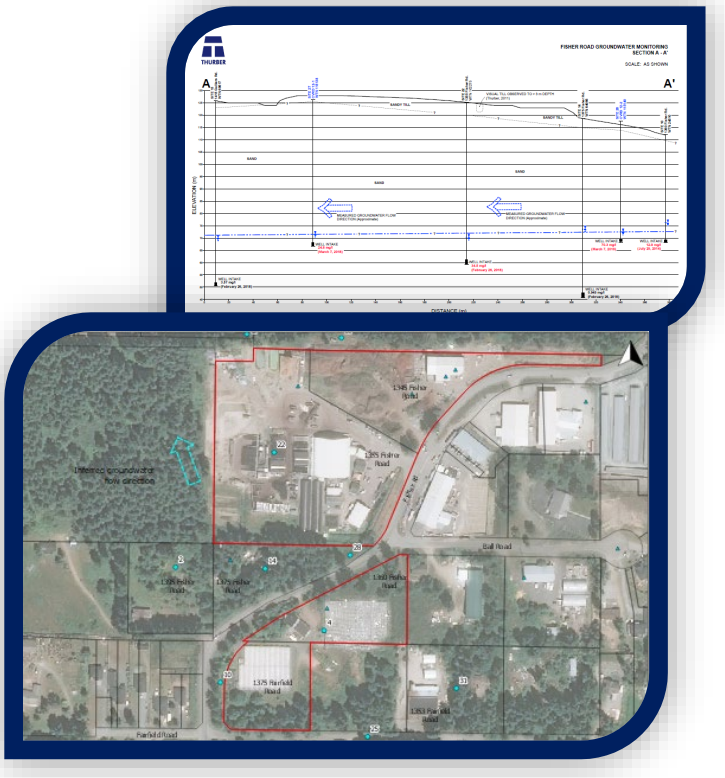
# Fisher Road Groundwater Investigation Data Review Report




*Prepared for:*

***Cobble Hill Aquifer Interagency Task Group***

## *FINAL REPORT*

*December 18, 2018*
*Project: 18-052-01*

*Prepared by:*

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## Executive Summary

Western Water Associates Ltd. (WWAL), in partnership with Thurber Engineering Ltd. (Thurber), was retained by the Cobble Hill Aquifer Interagency Task Group (CHAITG) to conduct a desktop groundwater investigation for the Fisher Road area in Cobble Hill, BC. Based on previous studies, there are at least two known groundwater plumes of nitrate contamination sourced from the areas of 1345 Fisher Road, 1355 Fisher Road and 1360 Fisher Road (Thurber, 2013, 2014a, 2014b). The overall goals of this study were to consolidate and review available hydrogeological and water quality data for the area to: characterize groundwater conditions, identify present and historical nitrate sources from land uses in the area (with emphasis placed upon previously identified sources), and evaluate the extent of present and predicted impacts to groundwater users.

The following points are general conclusions from this study:

- The previous interpretations regarding potential source sites for groundwater nitrate contamination remain valid.

- The groundwater quality data demonstrated that the Cobble Hill aquifer is vulnerable to nitrate contamination from many types of land uses, including commercial composting operations, agricultural greenhouse activities and septic inputs. The Fisher Road area also has current and historical farming activities that may have contributed to local groundwater nitrate concentrations.

- Groundwater nitrate concentrations that exceed regulatory standards have been detected in samples obtained from groundwater supply wells located at 1355 and 1360 Fisher Road, and three groundwater monitoring wells located on downgradient properties. Based on analysis of the compiled groundwater quality data, at present there is a low likelihood of impact to risk to previously unimpacted groundwater drinking water supply wells from the known nitrate contamination near 1345 Fisher Road, 1355 Fisher Road, and 1360 Fisher Road.

- The groundwater nitrate concentrations detected in the Fisher Road area most likely result from past surface activities. While high risk activities are continuing on some properties in the area, the effects of any recent process improvements conducted at respective facilities likely won't be seen in groundwater samples produced from the monitoring wells for some time. There is no evidence that discharge from septic systems has resulted in groundwater nitrate concentrations that exceed regulatory standards.

WWAL developed a spreadsheet database summarizing the water sampling points and water quality data used in this study. The following groundwater quality data were incorporated into the spreadsheet database as part of this study:

- Data obtained from samples collected from 15 groundwater wells in the Fisher Road area by the Ministry of Forests, Lands and Resource Operations and Rural Development (FLNRORD) in 2018.

- Historical data obtained from samples collected from an additional 21 locations collected by numerous entities dating back to 1978. The water quality results were digitized by the Cowichan Valley Regional District (CVRD) and provided to WWAL in MS Excel format.

The assessment compared groundwater quality data to current British Columbia Contaminated Sites Regulation (CSR) Schedule 3.2 Generic Numerical Water Standards (up to BC Reg. 196/2017) based on Drinking Water (DW) use. Using the new and historical data, WWAL updated the site plan and cross-sections for the area and created plots of temporal changes in water chemistry parameters of interest from selected sites.

WWAL developed a hydrogeological conceptual model of the site using results from previous work in the Fisher Road area. To discuss the effects of long-term pumping, a capture zone for the well at 1355 Fisher Road (Site 22) was also created using estimated aquifer parameters and assumed pumping characteristics.

The following points summarize the technical findings of this study:

- Groundwater monitoring wells that produced samples which exceed CSR DW standard of 10 mg/L for nitrates included CVRD12-1, CVRD12-2, CVRD12-3. The groundwater supply wells at 1355 Fisher Road (Site 22) and 1360 Fisher Road (Site 4) have also produced samples found to exceed CSR DW for nitrates. No other groundwater nitrate concentrations exceeding 10 mg/L are known.

- The 2018 isotope data were consistent with previous sampling results suggesting that no change was required to previous interpretations regarding potential nitrate source sites. However, new isotope data from groundwater supply and monitoring wells at 1334 Fisher Road (Site 20), 1395 Fisher Road (Site 2), Cobble Hill Baptist Church (3791 Cobble Hill Road; Site 26), 1425 Gallier Road (Site 24), 1491 Gallier Road (Site 13), 1442 Gallier Road (Site 21), 1415 Gallier Road (Site 15), the well at the intersection of Gallier Rd & Holland Ave, 3720 Holland Ave (Site 18) and 3713 Holland Ave (Site 12) suggest that the relatively low nitrate concentrations in these wells may have originated from in-ground septic disposal or agricultural activities. The nitrate concentrations in these wells generally ranged from about 2 mg/L to 4 mg/L, which are higher than anticipated background concentrations of <1 mg/L, but lower than the applicable CSR DW standard of 10 mg/L.

- The property at 1375 Fisher Road (Site 14) is potentially down gradient of the known source of inorganic groundwater nitrate contamination at 1360 Fisher Road (Site 4) however, nitrate concentrations detected in the groundwater supply well on this property are low (<1 mg/L). 2018 isotope data from the residential supply well at 1375 Fisher Road (Site 14) suggested an isotopic signal consistent with organic-sourced nitrates. This suggests that the low nitrate concentrations in this well are likely not sourced from past up gradient commercial greenhouse operations at 1360 Fisher Road. Historical land use at 1360 Fisher Road may indicate potential for both inorganic and organic nitrate contamination (see Section 1.3 above). The groundwater supply well at 1375 Fisher Road is screened at significant depth below the groundwater table, while the nitrate concentrations near the surface of the groundwater table are unknown.

- The groundwater nitrate concentrations the plume(s) sourced from the past greenhouse operations at 1360 Fisher Road (Site 4) are decreasing, as observed at monitoring well CVRD12-2 and the water supply well located at 1355 Fisher Road (Site 22). There were insufficient data available to plot temporal changes in nitrate concentrations in samples obtained from the groundwater supply well at 1360 Fisher Road.

- The groundwater nitrate concentrations likely sourced from the composting facilities at 1345 Fisher Road and 1355 Fisher Road appear to be stable or increasing as observed at monitoring wells CVRD12-1 and CVRD12-3. From 2012 to early 2018, the available groundwater nitrate concentration data indicate that concentrations at CVRD12-3 have been increasing while the nitrate concentrations at CVRD12-1 have generally been stable. The extent of nitrate contamination in the area has not been delineated. There are no known wells located to the north (i.e. downgradient) of these groundwater monitoring well sites. The nearest known potentially downgradient water supply well is Site 15 (at 1415 Gallier Road), which is located about 150 m to the west of CVRD12-1. The 2018 data from the well at 1415 Gallier Road showed a nitrate concentration of 3.57 mg/L with an organic-sourced isotopic signature that is distinctly different from that observed at CVRD12-1. The well at 1415 Gallier Road is screened at about 20 m below the groundwater table while CVRD12-1 is screened about 2 m or 3 m below the water table. Typically, shallower screened wells show higher groundwater nitrate concentrations than deeper set wells.

- Additional, regularly-obtained groundwater data from dedicated new and existing groundwater monitoring wells would be required to delineate the areas of known groundwater nitrate contamination and to monitor nitrate fate and transport processes.

Recommendations provided in this report include:

- CHAITG should notify the current owners of the property at 1360 Fisher Road regarding the findings contained within this report and request that new samples be obtained from the supply wells located on the property and be tested for nitrate concentrations and isotopes. We understand that the owners of the property at 1355 Fisher Road are aware of the nitrate contamination issue and only use the water from their supply well for industrial purposes including site dust control and to provide moisture to compost piles.

- The apparent trends in groundwater nitrate concentrations at the four CVRD monitoring wells CVRD12-1, CVRD12-2, CVRD12-3 and CVRD13-4 and the supply well at 1355 Fisher Road (Site 22) require confirmation and intermittent monitoring through the collection and analysis of additional groundwater quality data, preferably as part of a biannual or annual groundwater sampling and analytical program.

    - CHAITG partners should collect data in a standardized format to facilitate database entry and future analysis, and review the data on a regular basis (e.g. 5 years).

- Biannual sampling would assist to capture seasonal variation in water chemistry. For example, samples should be collected at times of year when groundwater levels are near be highest and lowest (e.g. spring and late summer/early fall).

- Key parameters for analysis should include nitrate and nitrite concentrations, ammonia, total carbon, redox, dissolved oxygen and nitrate isotope data.

- Regular testing of municipal septic disposal monitoring wells and public and private residential water supply wells that are potentially located within or downgradient of groundwater nitrate plumes should also continue to be conducted on a regular basis.

- The nitrate source owners identified in this report should be encouraged and/or required (through regulatory, legal and other means) to address and monitor historical nitrate contamination sourced from their properties, as well as the current sources of nitrate under their control. While some of the specific recommendations below are already taking place, additional or improved measures may be required in some instances. Upcoming revisions to the Organic Matter Recycling Regulation (OMRR) may require facilities under permit to implement higher performance standards, including with respect to leachate and runoff management, and odour control.

    - The commercial compost operations should review and upgrade (where appropriate) their compost and wastewater handling and disposal procedures to prevent the infiltration of nitrogen compounds into the subsurface.

    - The compost facilities should install dedicated groundwater monitoring wells around their properties and implement approved regular groundwater monitoring programs. Additional study would be required to design and implement these programs. At a minimum, we believe there would be at least 3 to 5 additional monitoring wells needed to delineate a gross approximation of the boundaries for each nitrate plume.

    - The owner of the property at 1360 Fisher Road should conduct an environmental site investigation and remediate any known areas of soil contamination. The investigation should include the installation and monitoring of groundwater monitoring wells both on and beyond the property.

    - The owners of municipal and strata septic disposal systems should monitor and track their septic discharges. Municipal and provincial regulators should also place limits on development where nitrate loading to the aquifer may be greater than the aquifer's ability to absorb / denitrify the nitrate loading.

  - Groundwater quality results collected by CVRD, water system operators, and polluters should be submitted to and retained in the provincial Environmental Monitoring System (EMS) database. The risk to groundwater quality from land uses could be further evaluated using GIS approaches, including combining results of aquifer vulnerability (DRASTIC) mapping previously completed for the CVRD with a spatial assessment of potential contaminant sources based on land-use. The results of risk assessment mapping could then be used to inform regional and municipal government decisions regarding zoning and development permit applications.

- It is recommended that samples of septic sewage wastewater be collected from several of the local septic disposal systems and analyzed for nitrate nitrogen and oxygen isotopes. These isotope data could potentially be used as a "fingerprint" for septic discharges in the aquifer and compared with currently available isotope data obtained from the local groundwater supply and monitoring wells.

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December 18, 2018
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FILE: 18-052-01

**Re: Fisher Road Groundwater Investigation Data Review**

Western Water Associates Ltd. (WWAL) is pleased to provide this Data Review Report for the Fisher Road Groundwater Investigation to the Cowichan Valley Regional District.

We trust that the professional opinions and advice presented in this document are sufficient for your current requirements. Should you have any questions, or if we can be of further assistance in this matter, please contact the undersigned.

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## 1. INTRODUCTION

Western Water Associates Ltd. (WWAL), in partnership with Thurber Engineering Ltd. (Thurber), was retained by the Cobble Hill Aquifer Interagency Task Group (CHAITG) to conduct a desktop groundwater investigation for the Fisher Road area in Cobble Hill, BC. CHAITG members include the Cowichan Valley Regional District (CVRD), the Ministry of Environment and Climate Change Strategy (ENV), the Ministry of Forest, Lands, Natural Resource Operations and Rural Development (FLNRORD), Island Health (IH) and the Ministry of Agriculture (AGRI). This report summarizes available hydrogeological data and recent and historical groundwater quality data from a large number of private water supply and environmental monitoring wells located in the Cobble Hill area of the CVRD.

The CHAITG was established in 2017 to respond to concerns regarding high levels of contamination within the Cobble Hill Aquifer. The province is governed by a polluter pay principle under the Environmental Management Act (EMA) framework.

### 1.1 Objectives

The CHAITG conducted a program of groundwater sample collection at 15 monitoring and water supply wells in the Fisher Road area during 2018. The CHAITG 2018 data, along with available historical data were compiled and provided to WWAL for use as part of our assessment.

The scope of work for this assessment was to:

- Develop a hydrogeological conceptual model for the Fisher Road area;
- Characterize groundwater conditions within the Fisher Road area of the Cobble Hill aquifer based on available data compiled from various sources;
- Identify present and historical nitrate sources from land uses in the area, focusing primarily on the sites of previously identified concern;
- Develop a capture zone for the supply well at 1355 Fisher Road (Site 22) to analyze the effects on local groundwater flow from pumping at this well;
- Compare the available groundwater data to the current Contaminated Sites Regulation numerical generic water quality standards based on Drinking Water use;
- Provide a discussion of the technical aspects of the groundwater nitrate contamination; and,
- Evaluate the extent of present and predicted future impacts to groundwater users based on data review.

### 1.2 Study Limitations

A large amount of water quality and other data collected and analyzed by others formed the basis of this study. It was not part of WWAL's scope of work to conduct any validation or quality control checks on the data; unless otherwise stated, the data were taken at face value for incorporation into the report. WWAL did not collect any environmental samples as part of this assessment.

Only groundwater sampling data provided to WWAL by CHAITG and partners were used in this study. Historical surface water quality data from samples collected from leachate ponds and swales at the composting operations at 1345 and 1360 Fisher Road and the past greenhouse operations at 1360 Fisher Road were compiled by CHAITG and partners as part of this study; however, interpretation of the surface water samples was not within the scope of the current study. The reader should refer to Thurber (2013) for additional information on leachate sampling and interpretations.

Delineating nitrate contamination plumes and sources requires a comprehensive dataset of groundwater samples collected from a number of spatially and temporally distributed points. The data set for this study included sampling results from only four purpose-built groundwater monitoring wells in the study area, in addition to a number of residential and commercial supply wells that were broadly distributed throughout the region. Due to the limitations in the spatial and temporal distribution of the dataset, it is not possible to make accurate predictions of contaminant fate and transport at this time.

### 1.3 Study Area

The study area is underlain by the Cobble Hill Aquifer, which is the western portion of the larger Cherry Point Aquifer (#197) (ENV, 1996). Groundwater supply from the Cherry Point aquifer is used for irrigation, commercial, and municipal domestic purposes. The Cherry Point aquifer has been described by the ENV as comprising about 39 $km^2$ in areal extent, being located on the south side of Cowichan Bay, and extending south to Mill Bay and southwest to Shawnigan Creek. Its western boundary is the base of Cobble Hill and the Dougan Lake Aquifer, while the eastern boundary is Arbutus Ridge. This variably sorted sand, gravel and silt aquifer is described as being confined and having moderate productivity. A regional groundwater flow direction has not been determined but the local groundwater flow direction in the Fisher Road area is north-northwesterly towards Cowichan Bay.

ENV information on the aquifer originally indicated that the Cherry Point aquifer had a low vulnerability to surface contamination due to the presence of overlying low permeability marine and glaciomarine deposits including clay and till. However, in many places in the Fisher Road area of Cobble Hill, the overlying low permeability soils are either thin, discontinuous or absent and the sediments often exhibit continuous permeable granular materials from the surface to depths greater than 60 m. Groundwater levels in this area typically range from about 30 m to 60 m below the surface.

Nitrate contamination of the aquifer was initially identified in the Fisher Road area through groundwater sampling conducted by the ENV in 2002. Between 2011 and 2014, Thurber was retained by the CVRD to conduct several phased environmental and groundwater assessment studies that included the

installation of dedicated groundwater monitoring wells (CVRD12-1, CVRD12-2, CVRD12-3 and CVRD13-4). This prior work led to the identification of at least two distinct plumes of groundwater nitrates (and their likely sources) in the area (Thurber, 2011a, 2011b, 2013, 2014a, 2014b).

The nitrate contamination observed in monitoring wells CVRD12-1, CVRD12-2 and CVRD12-3 was interpreted as being at least partially sourced from historical operations at 1345 Fisher Road, 1355 Fisher Road, and 1360 Fisher Road. Thurber (2011a) provided detail on historical land use in the Fisher Road area. Thurber (2011a) summarized the current and past site activities for these locations as follows:

- 1345 Fisher Road – Currently occupied by Central Landscaping Ltd. (CLS). CLS is a yard and garden waste recycling facility, with an outdoor composting area located on the west side of the property. Previous uses may have also included commercial poultry operations.

- 1355 Fisher Road – Currently occupied by Fisher Road Recycling Ltd. (FRR). FRR is a commercial organic material composting facility and recycled materials drop off and transfer station. In addition, FRR uses water from the on-site groundwater well for dust suppression (discussed in further detail in Section 4.2.1). We understand there have been upgrades to the site and operations since the Thurber report was issued.

- 1360 Fisher Road – Previously occupied by Gamboa Greenhouses. This was a greenhouse operation producing tomatoes, cucumbers and peppers, and the greenhouse waste was composted onsite. Previous uses may have also included commercial poultry operations.

We understand that the owners of CLS were recently issued a Pollution Prevention Order (#109687) for storing wood waste, compost, and leachate in a manner likely to release leachate into the environment causing pollution (ENV, 2018b). The owners of CLS have been ordered to complete a series of improvements to the leachate system, which include mitigating leachate discharge into the environment, and proposing an action plan for the leachate control system improvements.

## 2. METHODOLOGY

### 2.1 Groundwater Sampling and Analysis

The data provided to WWAL were originally collected by a number of parties, including CHAITG members (and their consultants) for a variety of purposes including groundwater quality monitoring, supply well assessment, environmental investigation and regional groundwater characterization. The locations of groundwater sampling points are shown on Figure 1 in Appendix A.

The water sample analyses were conducted by at least nine different analytical laboratories, primarily between 2000 and 2018, although some older data (from 1978 and the 1990s) have also been provided. The analyses conducted were highly variable, depending on the source (who collected the data and when) but generally included a range of routine parameters (conductivity, pH, turbidity, hardness, alkalinity, anions, cations and others), nitrogen concentrations (nitrogen, nitrate, ammonia, etc.), total

and/or dissolved metals, some microbiology and other parameters, most notably nitrate nitrogen and oxygen isotopes.

The quality assurance / quality control procedures employed as part of the sample collection and analyses are unknown, but likely varied with each data source and sampling event.

### 2.2 Groundwater Quality Database

The database was constructed for analytical purposes and includes six separate tabs as follows:

- **Well Key** – Locational and identifying information for the wells for which data were available. The well key organizes 36 sampling points by well tag number (WTN) and by site number assigned to each sampling point. Included are well depths and construction information, where available, and a link to the well log in the GWELLS database.

- **Master Spreadsheet** – Summary table that presents most of the available groundwater data. This summary table contains results from 239 water quality samples which correspond to sampling points.

- **WQ Figures** – Nitrate data summary charts (Figures 5 to 10).

- **Isotope Chart** – Chart that summarizes/interprets the available nitrogen and oxygen isotope data (Figure 11).

- **1355 Fisher Road Data** – Large amount of available analytical data for the composting facility at 1355 Fisher Road (Site 22) including historical water quality data for the on-site water supply well (S1), surface water data from the swale / infiltration ditch (S2) and a number of leachate ponds.

- **Explanatory Notes** – Information relating to the data and environmental standards included on the Master Spreadsheet tab.

The database was created in tandem by CVRD and WWAL, with data entry primarily conducted by the CVRD. While the data have been reviewed by WWAL, most of the data have not been compared with the original text version and as such, translation errors may be present.

Groundwater well locations were referenced using their WTN and ENV's online GWELLS groundwater well database system (ENV, 2018a). For wells without WTNs, the wells were referenced using sketches provided by CVRD or by municipal address listed on the hard copy lab report. Lab reports for surface water samples, and those with no WTN or municipal address were included in the database but generally disregarded for the analysis.

The groundwater data shown on the Master Spreadsheet have been compared to current British Columbia Contaminated Sites Regulation (CSR) Schedule 3.2 Generic Numerical Water Standards (up to

BC Reg. 196/2017) based on Drinking Water (DW) use, which were shown on the far right-hand side of the table. Standards for groundwater samples for heavy metals and metalloids (i.e. arsenic) were based on dissolved substance concentrations. Parameters on the table that exceed DW standards have been bolded and highlighted in orange. Wells that have produced water samples that were found to contain nitrate concentrations that exceed CSR DW standards were highlighted in orange on Figure 2 in Appendix A. Note that the CSR standard for nitrate is the same as the Guideline for Canadian Drinking Water (10 mg/L).

Evaluation of the isotopic ratios of nitrate (including $^{15}N$ and $^{18}O$) in the CVRD monitoring wells and potential sources of nitrate on the surface, including fertilized irrigation water at 1360 Fisher Road and compost leachate at 1355 Fisher Road (Site 22), was initially conducted by Thurber in 2013. Nitrates sourced from inorganic chemical fertilizers have an isotopic signature that is different and distinct from nitrates sourced from the breakdown of various types of organic matter, such as those derived from manure or septic sources or other types or organic waste.

The nitrate isotope data have been plotted on an X-Y chart labelled "Figure 11 - NO3 Fisher Road Isotope Data" (Appendix B) as a means of identifying potential nitrate sources and for characterizing the groundwater nitrates at isotope sampling locations. On the chart, $^{15}N$ ratios were plotted along the "X" axis, while $^{18}O$ ratios were plotted along the "Y" axis. The chart includes five labelled areas of common $^{15}N$ / $^{18}O$ nitrate composition marked by different dashed and solid black boxes. These "zones" delineate typical isotopic ranges for nitrate originating from different sources. The nitrate source zones shown on the chart include: inorganic-sourced nitrates originating from precipitation inputs, nitrate sourced from synthetic nitrate fertilizers (which are derived from atmospheric nitrogen) and desert nitrates. Organic-sourced nitrates include those derived from the breakdown of organic matter such as manure and septic waste and the breakdown of organic material in soil. The isotopic ranges for the different source zones shown on the chart were obtained from Kendall (1998).

### 2.3 Groundwater Level Monitoring

Groundwater levels were monitored at well locations CVRD12-1, CVRD12-2, CVRD12-3 and CVRD13-4. Each of the continuous monitoring locations have data-logging transducers, capable of measuring temperature and pressure. In November 2013, the datalogger installed in CVRD12-2 was relocated to CVRD13-4. Water level data were downloaded by FLNFRORD from the dataloggers and provided to WWAL for this study. This dataset was also compared to water levels obtained from the ENV's observation well number 320 (ENV #320), located nearby.

Hourly water level data were collected in four of the monitoring wells using transducers that automatically log pressure readings at set intervals. The data were converted to water levels by subtracting barometric pressure from the total pressure measured in the wells. Well elevations were surveyed during previous work to convert the recorded groundwater levels into elevations above sea level. Groundwater elevations collected since the dataloggers were installed in the Fall of 2012 are shown in Figure 4.

### 2.4 Well Capture Zones

WWAL analyzed the effects of local groundwater extraction by delineating the capture zone for the well at 1355 Fisher Road (Site 22) using the analytical solution methodology from the Well Protection Toolkit (ENV, 2006). The capture zone is depicted in Figure 12 at the end of Appendix A.

## 3. RESULTS

### 3.1 Hydrogeological Conceptual Model

A conceptual hydrogeological model is a qualitative representation of a study area, which is used to describe the occurrence and flow of groundwater through the subsurface. The process of developing a conceptual model includes subdividing the subsurface into hydrostratigraphic units (e.g. aquifers and aquitards) based on their relative estimated hydraulic properties. Conditions bounding the system are identified, including: established groundwater levels, surface water bodies and watercourses, barriers to flow, and areas of groundwater recharge and discharge. Groundwater flow patterns are identified based on the interpreted hydraulic gradients.

WWAL developed a hydrogeological conceptual model for groundwater flow in the Fisher Road area. The model is considered preliminary as there are significant gaps in available data used to develop the model. As is typical with conceptual models, the one developed here can be updated and improved as new data become available.

#### *3.1.1 Hydrostratigraphic Units*

Hydrostratigraphic units are groupings of geologic units having similar hydraulic conductivity and storage properties. Hydrostratigraphic units are designated as either aquifers (units conducive to groundwater flow) or aquitards (units that impede groundwater flow).

The major hydrostratigraphic units in the study area were defined based on the available surficial geology information, inferred hydrogeological parameters, and other data where available. The hydraulic parameters of these units are discussed in relative terms due to a lack of quantitative hydraulic testing. The designation of aquifers versus aquitards is relative to this specific hydrogeologic setting and the scale of the study area.

For the purposes of this study, two distinct hydrostratigraphic units were defined:

- Unit A – Surficial Aquitard
- Unit B – Sand and Gravel Aquifer

Aquifers are unconfined where they are the uppermost hydrostratigraphic unit and are confined where they are capped or overlain by aquitards, and the water levels in wells rise above the aquifer/aquitard contact. Partially confined aquifers exist where the overlying aquitard is not continuous.

<u>Unit A – Surficial Aquitard</u>

The surficial aquitard in the area is discontinuous and is comprised of near-surface clay and/or till deposits which are generally low permeability. Unit A is discontinuous in the study area but has a maximum thickness of 20 m when present. When present, this unit acts as a confining layer to Unit B.

Unit B – Sand and Gravel Aquifer

Unit B is present throughout the study area and is comprised of glaciofluvial deposits (Blythe et al., 1993) which are generally highly permeable. The water levels are at least 30 m below ground surface within this unit. ENV (1996) classified the Cobble Hill aquifer as a confined aquifer (described in detail in Section 1.1 above). Within the study area, Unit B is unconfined from a hydraulic standpoint but protected from above by Unit A (where present). Groundwater levels fluctuate seasonally by about 0.5 m to 1 m within this unit.

The hydraulic conductivity (K) of the material was previously estimated to be on the order of $10^{-5}$ m/s (Thurber, 2011b), which is approximately the middle point of silty sand according to Freeze & Cherry (1979). Based on an estimated saturated thickness of 50 m, the transmissivity of Unit B was estimated to be 0.005 $m^2/s$. The true thickness of Unit B is unknown, as none of the groundwater wells in the area fully penetrate this layer.

### *3.1.2 Groundwater Levels*

Measured groundwater levels obtained from four Fisher Road monitoring wells (including CVRD12-1, CVRD12-2, CVRD12-3 and CVRD13-4) are shown on the attached Figure 4 in Appendix A. The water levels were obtained from both automatic data logger readings and manual measurements. Both CVRD12-1 and CVRD12-3 had measurement data for September 2012 to March 2018 while shorter water level records were available for CVRD12-2 (September 2012 to December 2013) and CVRD13-4 (November 2013 to March 2018). Measured precipitation for the time-period (obtained from nearby Environment Canada Weather Station 'Duncan Kelvin Creek' (Climate ID: 101253) is also shown on the lower portion of the figure.

### *3.1.3 Groundwater Recharge and Discharge*

Infiltration of precipitation and surface water is regarded to be a widespread source of groundwater recharge in the area. However, where the surficial aquitard is present, the majority of infiltrating precipitation may flow laterally and discharge downslope rather than recharging the aquifer. Deep aquifers may receive significant recharge from precipitation where they are unconfined. Upward and lateral flow of groundwater from bedrock may also contribute to the recharge of deep aquifers.

### *3.1.4 Groundwater Flow*

Based on 2018 water level readings at CVRD12-1, CVRD12-2, CVRD12-3, and CVRD13-4, the regional groundwater flow direction in the Fisher Road area was towards the north-northwest with a gradient of approximately 0.004 (0.4%).

The groundwater flow direction in the area of 1345 Fisher Road, 1355 Fisher Road and 1360 Fisher Road is well-known from previous study conducted by Thurber (2011a, 2011b, 2013, 2014a, 2014b). The groundwater flow direction measured as part of this study was consistent with previous water level measurements. The average flow velocity in the aquifer was calculated to be approximately 0.01 m/day based on the measured gradient and assumed aquifer properties. There are insufficient water level data currently available to accurately determine the groundwater flow direction and gradients in areas away from Fisher Road.

It should be noted that all groundwater supply and monitoring wells are located downgradient of multiple potential source sites, which complicates the identification of specific nitrogen sources. An example is monitoring well CVRD12-3 (Site 29), which is located down gradient of both commercial composting operations at 1345 and 1360 Fisher Road (as well as the past commercial greenhouse operation at 1360 Fisher Road).

## 3.2 Groundwater Chemistry

### *3.2.1 Metals*

The following summarize our assessment of the available groundwater metals data.

- Dissolved metals concentrations that exceeded CSR DW standards were very rare in the data provided with only one instance of a standards exceedance. Dissolved nickel was detected at a concentration of 0.0807 mg/L in the September 17, 2012 sample obtained from the CVRD12-2 well. This exceedance was marginal as the CSR DW standard for nickel is 0.08 mg/L. It should be noted that many of the wells / samples only had total metals data available, which are not directly comparable to the CSR standards for metals in groundwater, which are based on dissolved metals concentrations.

- High total metals concentrations were detected in a number of wells, particularly the CVRD12-1, CVRD12-2, CVRD12-3 and CVRD13-4 monitoring well samples. These results were very likely the result of the analysis of turbid water samples and the dissolution of metals from suspended sediment. The turbidity of the samples collected from the CVRD monitoring wells were all very high (up to 6000 Nephelometric Turbidity Unit (NTU)) and as a result, the total metals concentrations from these wells may be discounted as being unrepresentative of the dissolved groundwater conditions. The dissolved metals concentrations in these wells were significantly lower than the total metal concentrations and were less than CSR DW standards (not counting the exceedance noted above).

### *3.2.2 Nitrates*

- Review of the histogram of available groundwater nitrate data (Figure 5 in Appendix 2) suggests that the Fisher Road area may have a background groundwater nitrate concentration of <2 mg/L, as was evidenced by the many groundwater samples that were collected and found to have

nitrate concentrations significantly less than 2 mg/L. A large proportion of the available data also include nitrate concentrations in the range of 2 mg/L to 4 mg/L. However, it remains unclear if nitrate concentrations in this range represent naturally-occurring background concentrations (i.e. derived primarily from naturally occurring soil nitrate), or possibly indicate more widespread, lower-level anthropogenic inputs (i.e. septic disposal or agricultural inputs etc.) or more concentrated natural sources. Choi et al (2003) have noted when nitrate concentrations are consistently in the range of 3 mg/L or below, and $^{15}N$ values in the range of +5 to +8 ‰, naturally occurring soil nitrogen can be assumed as the source.

- Recent work by the FLNRORD (in progress) indicated that the median nitrate concentration from supply wells in the south Cowichan region is close to 0.1 mg/L (Barroso et al., 2018), which suggests that background nitrate concentrations in the area could be lower than 2 mg/L. From the south Cowichan groundwater quality study and a related study in South Wellington, FLNRORD observed that the majority of the rural residential sites sampled all had onsite septic systems, but observation of nitrates above 2 mg/L was rare and generally attributed to land activities expected such as agriculture (Barroso et al., 2015; Barroso, 2018). However, large volumes of in-ground sewage disposal could also contribute to nitrate loading.

- Relatively few samples had nitrate concentrations between 6 mg/L and 20 mg/L, while approximately 65 samples in the dataset had concentrations greater than 20 mg/L, which reflects the higher sampling frequency in a relatively small area of known groundwater nitrate contamination near Fisher Road.

- As shown on Figure 2, wells that produced groundwater samples containing nitrates at concentrations that exceed the CSR DW standard of 10 mg/L were collected from the following wells:

    - WTN 24510 – Water supply well at 1360 Fisher Road (Site 4). The property has a long history of commercial greenhouse use where nitrate-fertilized irrigation water was used. We understand greenhouse operations ceased at this property in 2017. Prior to the greenhouses, the property at 1360 Fisher Road was occupied by a commercial poultry barn.

    - WTN 102275 – Water supply well at 1355 Fisher Road (Site 22). This property is the site of a long-time commercial composting operation (FRR). We understand that the water from this well is only used for industrial purposes.

    - WTN 115138 - CVRD12-1 (Site 27) - Groundwater monitoring well north of the composting facility at 1355 Fisher Road.

    - WTN 115140 - CVRD12-2 (Site 28) - Groundwater monitoring well in the road right-of-way north of the previous commercial greenhouse operation at 1360 Fisher Road.

- WTN 115141 - CVRD12-3 (Site 29) - Groundwater monitoring well north of the property at 1345 Fisher Road, which is the site of a second, long-time commercial composting business (CLS).

These nitrate data are discussed in greater detail below.

- The nitrate concentration data for the drinking water supply well at 1360 Fisher Road (Site 4) consisted of four data points including two separate samples collected on the same day in 2002 (possible duplicate samples), one sample collected in 2010 and another in 2014. The two samples collected in 2002 contained similar nitrate concentrations (i.e. 7.51 mg/L and 8.69 mg/L) that were less than the guideline concentration of 10 mg/L but were significantly elevated above anticipated background concentrations. The 2010 sample contained a concentration of 17.1 mg/L and the 2014 sample had a concentration of 12.9 mg/L. The limited amount of data available for this residential / commercial-use well prevented the assessment of nitrate concentration trends over time. It should also be noted that nitrate concentrations at a given location can vary significantly through the seasons in response to recharge events that may mobilize available soil nitrogen into the aquifer.

- Plots of the nitrate concentration data for the three CVRD monitoring wells located to the north and south of 1355 Fisher Road (Site 22) (i.e. CVRD12-1, CVRD12-2 and CVRD12-3) are provided in Appendix B as Figures 7, 8 and 9. These wells were purpose-built to monitor the shallow groundwater conditions (a few meters below the top of the groundwater table) both north and south of the property at 1355 Fisher Road (Site 22). Only five data points were available for each of the CVRD monitoring wells between 2012 and 2018. There was a 3.5-year gap during 2015, 2016 and 2017 where no environmental sampling was conducted.

  Despite the limitations in the available data, some apparent trends in the data from these monitoring wells were evident. The groundwater nitrate concentrations at CVRD12-1 (north of 1355 Fisher Road) were variable with concentrations ranging between about 23 mg/L and 34 mg/L with no apparent upward or downward trend in the available data, suggesting seasonal variations are possible. At CVRD12-2 (located in the Fisher Road right-of-way between 1355 Fisher Road and 1360 Fisher Road) the water samples collected during 2012-2014 were consistently high, ranging from about 92 mg/L to 98 mg/L, while the latest sample (collected in 2018) showed a lower nitrate concentration at about 70 mg/L. It is unclear if this most-recent lower data point signifies a trend of decreasing groundwater nitrate concentrations at CVRD12-2.

- The nitrate data for CVRD12-3 (north of the property at 1345 Fisher Road) suggested an increasing trend of groundwater nitrate concentrations, which have increased with each successive sampling event since 2012. The nitrate concentrations detected in samples collected from CVRD12-3 during 2012-2014 ranged from about 15 mg/L to 20 mg/L, while the 2018 sample had a concentration of 27.5 mg/L.

- Nitrate concentration data for the industrial well at 1355 Fisher Road (Site 22) were available from 2002 until 2018 however, the availability of data obtained prior to 2007 was limited. A plot of the nitrate concentration data from this well over time is provided in Appendix B as Figure 6. The data indicated that the nitrate concentrations in the well were highly variable over relatively short time periods with concentrations ranging by as much as 30 mg/L to 40 mg/L between sampling intervals. This short-term variation may be the result of intermittent pumping of the well or seasonal variations. Despite the short-term variability in the groundwater nitrate concentrations detected, Figure 6 shows an apparent trend of decreasing concentrations (from about 70 mg/L average to about 30 mg/L average) in the 11-year period since 2007.

- Nitrate concentrations in the water samples collected from the domestic water supply wells at 1375 Fisher Road (Site 14) and 1425 Gallier Road (Site 24) (both located near known areas of groundwater nitrate contamination) were consistently less than drinking water quality guidelines. It is suspected that the nitrate concentrations are low in these residential-use wells as the wells are screened at significant depths below the top of the local groundwater table (see Thurber cross section drawing Figure 3 in Appendix A). Nitrate concentrations in the shallow part of the aquifer at these locations may be significantly higher but have not been detected, as there are no shallow wells in the area.

- One of the longest sets of groundwater nitrate concentration data was provided by well WTN 54090 (Site 9 on Figures 1 and 2) which was intermittently sampled between 2002 and 2018 (see Figure 10 in Appendix B), as it is part of the Cobble Hill Improvement District water supply system. WTN 54090 is approximately 400 m west of the western property boundary at 1355 Fisher Road. The nitrate concentration data for the water samples collected from WTN 54090 were relatively consistent and ranged between about 3 mg/L and 4 mg/L. Figure 10 shows no real significant long-term trend although large gaps in the data may hide shorter-term trends.

- Denitrification is a process where nitrate is reduced to molecular nitrogen ($N_2$) through a series of intermediate products, facilitated by anaerobic bacteria. Anaerobic bacteria perform denitrification as a type of respiration that reduces oxidized forms of nitrogen in response to the oxidation of an electron donor, such as organic matter. Evidence of denitrification is usually seen in groundwater samples as elevated intermediate products, such as nitrite and organic carbon. There are insufficient groundwater chemistry data available from groundwater samples produced from CVRD12-1, CVRD12-2, CVRD12-3 and the well at 1355 Fisher Road (Site 22) to comment on denitrification of these wells.

### *3.2.3 Nitrate Isotopes*

- The 2018 and historical nitrate isotope data are shown on Figure 11 in Appendix B. The 2018 CVRD monitoring well isotope data were consistent with previous sampling results suggesting that no change was required to previous interpretations regarding potential source sites.

The isotope data indicated that multiple distinct plumes of groundwater nitrate contamination originating from multiple sources exist in the area, including one or two organic-sourced plumes of nitrate contamination seen in wells CVRD12-1 and CVRD12-3 which are located north (i.e. downgradient) of the commercial composting facilities at 1355 and 1345 Fisher Road. Another distinct plume of inorganic-sourced nitrate contamination extends north-northwestward from the previous site of the commercial greenhouses at 1360 Fisher Road to CVRD12-2 and extends to the water supply well at 1355 Fisher Road (Site 22).

- The 2018 isotope data from the residential supply well at 1375 Fisher Road (Site 14) suggested an isotopic signal consistent with organic-sourced nitrates, similar to the signals observed at CVRD12-1 and CVRD12-3 (north of the composting facilities). This suggested that the low nitrate concentrations in this well (<1 mg/L) have not been impacted by inorganic nitrates sourced from 1360 Fisher Road, which was somewhat in contrast with its proximity to CVRD12-2 which had strong signal of inorganic-based nitrate concentrations. The well at 1375 Fisher Road (Site 14) is screened at more than 25 m below the groundwater table, however, while CVRD12-2 is screened at a shallow depth, about 3 m below the groundwater table. The origin of the low organic-based nitrate signal in the well at 1375 Fisher Road (Site 14) is unknown but it may be naturally-occurring.

- The 2018 isotope data for 1334 Fisher Road (Site 20), 1395 Fisher Road (Site 2), Cobble Hill Baptist Church (3791 Cobble Hill Road; Site 26), 1425 Gallier Road (Site 24), 1491 Gallier Road (Site 13), 1442 Gallier Road (Site 21), 1415 Gallier Road (Site 15), the well at the intersection of Gallier Road & Holland Ave (Site 9), 3720 Holland Ave (Site 18) and 3713 Holland Ave (Site 12) were all clustered together within the lowest portions of the overlapping “Soil N” and “NO3 in Manure and Septic Waste” source zones on the isotope data chart (all have negative 18O ratios). The isotopic signal from these wells was relatively distinct from the other organic-based nitrate signals observed in the CVRD12-1 and CVRD12-3 wells indicating a potentially different organic source. Most of these well sites are located west or northwest of 1355 Fisher Road at locations potentially impacted by in-ground septic disposal and/or agricultural sources, and have nitrate concentrations ranging from about 2 mg/L to 4 mg/L, which were generally higher than anticipated background concentrations of <1 mg/L but lower than applicable CSR DW standards.

### 3.3 Analytical Capture Zone Delineation

The effects of groundwater extraction from the well at 1355 Fisher Road (Site 22) were analyzed by delineating a capture zone for the well using estimated aquifer properties, including: hydraulic conductivity (K), hydraulic gradient (i), transmissivity (T), porosity (n), and three different assumed pumping rates (Q). Flow rates of 10 $m^3$/day, 50 $m^3$/day and 100 $m^3$/day were chosen to depict assumed minimum and maximum values. The actual industrial well pumping rates at 1355 Fisher Road are unknown and likely vary significantly.

The resulting capture zone is provided in Figure 12 in Appendix A. The areal extent of the capture zone was depicted as patterned shades of blue. The solid-blue pattern was estimated using a pumping rate of 10 $m^3$/day, the medium-blue pattern used a rate of 50 $m^3$/day, and the light-blue pattern reflects a

pumping rate of 100 $m^3$/day. The analysis assumed that flow rates were held constant over each travel time period, however it is likely that the well was pumped intermittently at variable rates. The other parameters used to estimate the capture zone are described in Section 2.4. Further discussion on the effects of groundwater pumping is provided in Section 4.3 below.

## 4. CONCLUSIONS

### 4.1 General

Although the aquifer in Cobble Hill is protected in some areas by the presence of lower permeability overlying sediments, the current and prior studies have shown that locally the aquifer is vulnerable to contamination from the land surface, as indicated by areas where nitrate is significantly above background concentrations. The groundwater quality data demonstrated that the Cobble Hill aquifer is vulnerable to nitrate contamination from many types of land uses, including commercial and agricultural activities and septic discharges.

Based on analysis of the compiled groundwater quality and groundwater well data, the relative risk to existing domestic water supply wells previously impacted by nitrate contamination sourced from 1345 Fisher Road, 1355 Fisher Road, and/or 1360 Fisher Road, is considered to be low. There are no registered supply wells located within approximately ~500 m downgradient of 1345 Fisher Road and 1355 Fisher Road. Excluding the supply wells at 1355 and 1360 Fisher Road, nitrate concentrations in groundwater samples produced from supply wells near these locations are currently below CSR DW standards. This may be because the plume has not reached the well(s), or there is vertical distance between screened intake for these wells and the plume. However, these observations are based on limited data as the intermittently obtained water quality results from the supply wells may not suitably represent groundwater conditions in the aquifer.

Due to groundwater travel times, nitrate concentrations detected in groundwater monitoring wells CVRD12-1, CVRD12-2, CVRD12-3 represent past inputs sourced from 1345 Fisher Road, 1355 Fisher Road, and 1360 Fisher Road. We understand that the composting facility at 1355 Fisher Road has been upgraded their facility and/or operations in 2017 and 2018. Due to the time required for transport processes, it is unlikely that the improvements at this facility were captured in the 2018 samples from CVRD12-1 and CVRD12-3. The effects of any improvements at 1355 Fisher Road won't be seen in groundwater samples produced from CVRD12-1 and CVRD12-3 for some time. The composting facility at 1345 Fisher Road was recently issued a Pollution Prevention Order which outlined various improvements to the leachate management system on this property, and thus improvements to this facility are expected to occur in 2019 (ENV, 2018b).

Delineating nitrate contamination plumes and sources is a complex undertaking and has not been conducted in the Fisher Road area. The data set for this study includes intermittently collected sampling results from both groundwater supply wells as well as a limited number of purpose-built groundwater monitoring wells. As nitrate contamination tends to be most pronounced in the upper few meters of an aquifer, not all of the supply wells are constructed to enable accurate mapping of contamination. The

dedicated monitoring wells typically have well screens installed near the upper water surface and so will tend to provide the most accurate indication of the extent of nitrate contamination. Pumping of supply wells can create hydraulic gradients that move the nitrate through an aquifer, and from shallower portions to deeper portions.

While water quality data obtained from supply wells are suitable for comparison to environmental standards based on human health (as humans consume the water from supply wells), the data from supply wells may not suitably represent the groundwater conditions for adequate assessment of the fate and transport of specific contaminants. For example, the CVRD monitoring wells are all screened over short intervals at similar shallow depths so that the data from these wells are all directly comparable to each other and provide a representative example of the groundwater chemistry at each screened interval. In contrast, water supply wells are screened at different depths using screens of differing lengths making inter-well data comparisons challenging. In addition, where the wells are actively being used for supply, different and variable pumping rates, locally change flow gradients and therefore effect contaminant transport processes. WWAL has limited information regarding the screen depths and intervals of most of the water supply wells for which data were available. The main utility of incorporating the supply well data is to determine whether or not consumption of water from that source would result in exceedance of drinking water guidelines.

It is presumed that pumping from the industrial supply well at 1355 Fisher Road (Site 22) likely has an effect on the short-term fluctuations in the measured nitrate concentrations in the well. If pumping ceased or if the well was pumped at a lower steady rate, the nitrate concentrations detected in the well could very well have been different than those measured. Similarly, the water supply well at 1375 Fisher Road (Site 14) is screened at more than 25 m below the groundwater table and (as a domestic well) is likely operated at a lower long-term rate than the well at 1355 Fisher Road (Site 22). As a result, this well does not provide any information about the shallow groundwater conditions where the nitrate concentrations are likely to be the highest. Because of these observations, it is apparent that geochemical assessments of contaminant fate and transport based on data obtained from groundwater supply wells only provide a partial or general picture of the groundwater conditions and should be interpreted with caution. This has been found to be the case at other B.C. locations with nitrate contamination, such as the Abbotsford-Sumas Aquifer and the Hullcar Aquifer.

### 4.2 Nitrate Sources

Known or suspected sources of nitrate contamination and elevated nitrate concentrations in the Cobble Hill Aquifer include the commercial composting facilities at 1345 and/or 1355 Fisher Road, previous commercial greenhouse operations at 1360 Fisher Road (Thurber, 2011a, 2013, 2014a, 2014b) and municipal, strata and single-family septic disposal sites. While field-based agriculture is another potential source of groundwater nitrates, the available data were generally insufficient to adequately assess this potential source. This region has a history of agricultural activities that may have contributed to nitrate concentrations in groundwater in the area. The Agricultural Waste Control Regulation and Environmental Farm Plan provide guidelines for best practices to reduce agriculture's impact on the environment (ARDCorp, 2018a), and nutrient management (ARDCorp, 2018b).

### *4.2.1 Composting Facilities*

As previously discussed (and shown on the attached Figure 1 and 2), CVRD12-1 (Site 27) and CVRD12-3 (Site 29) are located north of FRR at 1355 Fisher Road and CLS at 1345 Fisher Road, respectively. The operations at FRR and CLS are different, from both a regulatory and operations perspective. There are insufficient data available, however, to provide separate discussions of monitoring well results from CVRD12-1 and CVRD12-3, with respect to individual or specific facility operations at each site. Adding to the complexity, monitoring well CVRD12-3 is located down gradient of both composting operations.

The groundwater nitrate contamination plumes to the north of the composting facilities at 1345 and 1355 Fisher Road were identified in monitoring wells CVRD12-1 (Site 27) and CVRD12-3 (Site 29) based on measured shallow groundwater nitrate concentrations and isotopic chemistry (Thurber, 2013, 2014a, 2014b). As previously identified, the isotopic chemistry of these plumes continued to show a distinctly different signature from other plumes of nitrate contamination in the Fisher Road area (see Figure 11). The CVRD12-1 and CVRD12-3 monitoring wells have each been sampled five times since 2012 and indicated either static or increasing nitrate concentrations (Figures 7 and 9). The extent of the contamination in this area has not been delineated as there are no known wells located to the north (i.e. down gradient) of these well sites. The nearest sampled well is Site 15 (a residential supply well at 1415 Gallier Road), which is located about 150 m to the west of CVRD12-1. The 2018 data from the well at 1415 Gallier Road (Site 15) included a nitrate concentration of 3.57 mg/L with an organic-sourced isotopic signature distinctly different from that observed at CVRD12-1. The well at 1415 Gallier Road (Site 15) is also screened at about 20 m below the groundwater table (and thus unlikely to detect contamination in the upper part of the aquifer), while CVRD12-1 is screened at a shallower depth.

We understand that the composting operations at 1355 Fisher Road currently use well water for dust control, if non-contact water is unavailable. The environmental effects of using nitrate-contaminated well water for dust control are believed to be low, due to natural denitrification processes (described above in Section 3.2.2). However, there were insufficient data available to quantitively describe denitrification.

Management of risk at commercial composting sites similar to 1355 Fisher Road and 1345 Fisher Road is typically done through use of best practices, coupled with comprehensive monitoring programs (carried out by the property owners) appropriate with the site activities. While we understand through discussions with the CVRD that the actual compost processing and handing operations at the two composting sites are significantly different from each other, some significant compost handling improvements have been made at 1355 Fisher Road. In contrast, we understand that the owners of CLS were recently issued a Pollution Prevention Order (#109687) for storing wood waste, compost, and leachate in a manner likely to release leachate into the environment causing pollution (ENV, 2018b). The owners of CLS have been ordered to complete a series of improvements to the leachate system, which include mitigating leachate discharge into the environment, and proposing an action plan for the leachate control system improvements. The continued operation of both of these facilities poses an ongoing risk of groundwater nitrate contamination.

### *4.2.2 Greenhouse Operations*

The plume of groundwater nitrate contamination extending to the north of the property at 1360 Fisher Road was previously identified in monitoring well CVRD12-2 (Site 28) and in water supply wells at 1355 Fisher Road (Site 22) and 1360 Fisher Road (Site 4) based on measured nitrate concentrations and isotopic chemistry (Thurber, 2013; 2014a; 2014b). This plume of migrating nitrate contamination continued to exhibit an inorganic-sourced isotopic signature distinctly different from the signatures obtained from the plumes north of the composting facilities (Figure 11). Given the signature and the location of the plume, it is likely that this nitrate plume originated from the infiltration of fertilized irrigation water under the site greenhouses.

Nitrate concentration data from both the 1355 Fisher Road (Site 22) well and CVRD12-2 (Site 28) indicated that the nitrate concentrations in this plume have been decreasing or possibly migrating away (see Figures 6 and 8). The extent of the contamination is unknown but nitrates with similar isotopic signatures have not been detected in other sampled water supply or monitoring wells in the area. It should be noted that the groundwater nitrate contamination extending to the north of the property at 1360 Fisher Road is at least partially being removed from the system through pumping of the 1355 Fisher Road (Site 22) well (see Section 4.3 below). The potential fate of this contamination is unknown, however, we understand that the previous greenhouse operation is no longer in business. The greenhouses have collapsed, and the extent of suspected soil nitrate contamination on the property is unknown. Nitrate contaminated soil on the property, which is likely to be present under the former greenhouse footprints and locations where organic farm waste had been collected could continue to leach nitrate into the local groundwater for years.

### *4.2.3 Septic Sources*

Information on known local municipal and strata septic disposal sites was provided to us by the CVRD. Based on this information, the locations of these sites are shown on Figures 1 and 2 in Appendix A, and are described as follows:

- Municipal Hutchinson Road disposal site located about 700 m south-southwest of 1355 Fisher Road. This is a high treatment facility (Class A) that denitrifies its waste water to <10 mg/L.
- Municipal Gallier Road disposal site located about 780 m west of 1355 Fisher Road. This is a low treatment facility (Class C) that does not denitrify its waste water.
- School District disposal site located about 350 m east of 1355 Fisher Road at Ecole Cobble Hill Elementary (3642 Learning Way). Information regarding the level of treatment at this site was not provided.
- At least three strata-owned disposal systems in the Holland Avenue / Watson Avenue / Gallier Road neighbourhood west and southwest of 1355 Fisher Road. Information regarding the levels of treatment at these sites was not provided.

The large number of wells in the region with nitrate concentrations between 2 mg/L and 4 mg/L suggest local impacts from introduced nitrate sources. The origin of the elevated organic-sourced nitrates in these residential supply wells is unknown but their isotopic signature is significantly different from the other available isotopic data attributed to both inorganic / chemical fertilizer-sourced nitrate and other organic-

sourced nitrate derived from commercial composting. While the isotopic signal of the nitrates within these wells is potentially consistent with what could be expected from septic-sourced nitrate (we understand that some of these wells are monitoring wells for septic disposal sites), other organic-based sources of nitrate are possible (e.g. soil N). Many of these wells are located to the west and northwest of Fisher Road and are downgradient of known municipal and strata septic disposal sites (see Figure 2). Other wells with similar elevated nitrate concentrations were located to the east of the northern part of Fisher Road (i.e. see Site 20 and 33 at 1334 and 1309 Fisher Road on Figure 2), these sites are in close proximity or downgradient of a known septic disposal site at Ecole Cobble Hill Elementary at 3642 Learning Way.

### 4.3 Effects on Groundwater from Pumping at 1355 Fisher Road

A well capture zone illustrates the area of water (generally in two-dimensional, plan view) that will ultimately flow into a given well under an assumed set of conditions. It is specific to the pumping characteristics of the well and the flow parameters for the aquifer in which the well is completed. Capture zone can be distinguished from the zone of influence of a well, which is the surrounding area of measurable drawdown, or a recharge area, which is the zone that contributes water to the aquifer some of which might flow to the discharging well. One of the characteristics of highly transmissive aquifers is that pumping results in a wide radius of influence, but only a small amount of drawdown (e.g. a broad, flat drawdown cone). For poorly transmissive aquifers, pumping results in a narrow radius of influence and a large amount of drawdown. The aquifer is estimated to have a transmissivity of 0.005 $m^2/s$, and this value is considered moderately transmissive (Freeze & Cherry, 1979).

As discussed in Section 3.3, the effect of pumping the supply well at 1355 Fisher Road (Site 22) was assessed by estimating the well's capture zone. The previous greenhouse operations located at 1360 Fisher Road are situated within the 5-year capture zones for the well at 1355 Fisher Road (Site 22) (see Figure 12 in Appendix A). This is consistent with the isotopic signature of the groundwater samples collected at 1355 Fisher Road (Site 22) being from inorganic sources potentially sourced from 1360 Fisher Road. As the nitrate concentrations detected at 1355 Fisher Road (Site 22) have decreased over the sampling period, the well at 1355 Fisher Road (Site 22) is likely acting as a local sink, drawing contaminated water inward and removing it from the system through pumping.

As previously discussed, the highest nitrate concentrations in the Fisher Road area were observed to be present within the shallow portions of the water table. In addition to drawing water laterally inward, nitrate-contaminated groundwater could also be drawn downward through pumping of the supply well at 1355 Fisher Road (Site 22). Based on the information provided above for aquifer parameters and zone of influence characteristics, and the relatively low assumed operational rate for the well at 1355 Fisher Road (Site 22), it is likely that the zone of influence is localized.

### 4.4 Data Gaps

Additional, regularly-obtained groundwater data from dedicated new and existing monitoring wells would be required to monitor seasonal variation in nitrate concentrations, delineate the known groundwater

nitrate contamination plumes, and to monitor nitrate fate and transport processes. Recommendations for additional groundwater well installation and monitoring are included in report Section 5.

### 4.5 Regulatory Implications

The findings of this report indicated the presence of nitrate concentrations in groundwater that exceed applicable CSR DW Standards at various locations that are downgradient of suspected nitrate sources in the vicinity of Fisher Road. This apparent migration of contaminants beyond their point of origin is a concern from a regulatory perspective as there are regulatory requirements related to the migration of contaminants, including Section 60.1 (1) of the CSR which states:

> *A responsible person who carries out a site investigation that discloses that one or more substances has migrated or is likely to have migrated to a neighbouring site and is or is likely causing contamination of the neighbouring site must provide written notification described in subsection (2).*

Subsection (2) refers to notification of the BC Ministry of Environment and Climate Change Strategy and neighbouring property owners.

The contamination of non-source sites by migration through the groundwater could have significant implications for downgradient property owners including health concerns resulting from the consumption of nitrate contaminated groundwater, costs associated with either treatment or the provision of municipal water to replace contaminated supplies, decreased property values, potential environmental investigation requirements and limitations regarding future development options for the impacted sites.

### 4.6 Mitigation and Management

As mentioned above, breakdown of nitrate is known as denitrification, which is a microbially-facilitated process where nitrate is reduced to molecular nitrogen ($N_2$) through a series of intermediate nitrogen oxide products. Anaerobic bacteria perform denitrification as a type of respiration that reduces oxidized forms of nitrogen in response to the oxidation of an electron donor, such as organic matter. Denitrifying microbes require very low oxygen concentrations (i.e. less than 10%), as well as organic carbon for energy. Given the requirement for low oxygen environments in the denitrification process, it is likely that the potential for denitrification in the aquifer will increase with increasing depth below the groundwater table, which should result in a vertical gradient of decreasing nitrate concentrations. These gradients have not been confirmed in the Fisher Road area but are suspected based on the available data.

There are numerous studies and publications that address the mitigation and management of groundwater nitrate, however the key approaches include: nitrate source management, in-situ treatment (well injection), pump and treat (ex-situ treatment) and natural attenuation, and monitoring. Source management and natural attenuation and monitoring are by far the most cost-effective mitigation options. In-situ and ex-situ treatment are expensive but can be effective for high risk sites where high-level nitrate contamination is relatively contained and delineated.

## 5. RECOMMENDATIONS

Based on the findings of the study, a series of tasks have been recommended for additional study. Responsibilities for tasks and addressing recommendations in the study area are subject to CHAITG's discretion, and may be shared among different parties, including regulatory agencies, industrial operators, private property owners, water supply system operators (both private and public), and domestic well owners' responsibility to sample their own wells. The following recommendations are provided:

- While we are not aware that the drinking water supply well at 1360 Fisher Road (Site 4) has been sampled since 2014 when it was found to contain nitrates at 12.9 mg/L, considering the recent change in ownership of the property, we recommend that the CHAITG notify the current property owners regarding the findings contained within this report. The notification should include reference to the potential health hazards associated with the consumption of nitrate contaminated groundwater. The wells at 1360 Fisher Road and 1355 Fisher Road (Site 22) are the only known drinking water supply wells found that contain nitrates at concentrations exceeding the CSR DW standard of 10 mg/L. We understand that the owners of the property at 1355 Fisher Road are aware of the nitrate contamination issue and only use the water from the well for industrial purposes (site dust control and to provide moisture to compost piles).

- The apparent trends in groundwater nitrate concentrations at the four CVRD monitoring wells CVRD12-1, CVRD12-2, CVRD12-3 and CVRD13-4 and the supply well at 1355 Fisher Road (Site 22) require confirmation and monitoring through the collection and analysis of additional groundwater quality data, preferably as part of a biannual or annual groundwater sampling and analytical program.

    - CHAITG partners should collect data in a standardized format to facilitate database entry and future analysis. The data should be reviewed on a regular basis (e.g. every 5 years).

    - Biannual sampling would assist to capture seasonal variation in water chemistry. Samples should be collected in the winter and in the summer, when water levels would be highest and lowest.

    - Key parameters for analysis should include nitrate and nitrite concentrations, ammonia, total carbon, redox, dissolved oxygen and nitrate isotope data.

    - Regular testing of municipal septic disposal monitoring wells and public and private residential water supply wells that are potentially located within or downgradient of groundwater nitrate plumes should also continue to be conducted on a regular basis.

  Additional groundwater monitoring wells should be drilled and sampled at locations to the east, west and north of the nitrate source sites at 1345, 1355 and 1360 Fisher Road to permit the delineation and further monitoring of nitrate contamination in these areas. The wells should be screened at variable depths starting no more than 2 m below the groundwater table, as well as

deeper screened intervals to allow the vertical delineation of nitrate concentrations. All of the well screens should be no longer than 1.5 m in length (with sand packs no greater than 1.8 m length) to conform with ENV monitoring well guidelines. At a minimum, we believe there would be at least 3 to 5 additional monitoring wells required to determine gross approximation of the boundaries for each nitrate plume.

- The nitrate source owners identified in this report should be encouraged and/or required (through regulatory, legal and other means) to address and monitor historical nitrate contamination sourced from their properties, as well as the current sources of nitrate under their control. While some of the specific recommendations below are already taking place, additional or improved measures may be required in some instances. We understand the Province's Organic Matter Recycling Regulation (OMRR) is currently undergoing review. Upcoming revisions to the OMRR may require facilities under permit to implement higher performance standards, including with respect to leachate and runoff management, and odour control.

    - Commercial compost operations should review and upgrade their compost and wastewater handling and disposal procedures to ensure they are effective in preventing the infiltration of nitrogen compounds into the subsurface. As per Pollution Prevention Order #109687 (discussed above) (ENV, 2018b), CLS is now expected to complete a series of tasks to improve the leachate control system for their facility at 1345 Fisher Road in 2019.

    - The compost facilities should also install dedicated groundwater monitoring wells around their properties and implement approved regular groundwater monitoring programs.

    - The owner of the property at 1360 Fisher Road should conduct an environmental site investigation and remediate any known areas of soil contamination. The investigation should include the installation and monitoring of groundwater monitoring wells both on and beyond the property.

    - The owners of municipal and strata septic disposal systems should monitor and track their septic discharges. Municipal and provincial regulators should also place limits on development where nitrate loading to the aquifer may be greater than the aquifer's ability to absorb / denitrify the nitrate loading. Groundwater quality results collected by CVRD, water system operators, and polluters should be submitted to and retained in the provincial EMS database. The risk to groundwater quality from land uses could be further evaluated using GIS approaches, including combining results of aquifer vulnerability (DRASTIC) mapping previously completed for the CVRD with a spatial assessment of potential contaminant sources based on land-use. The results of a risk assessment mapping could then be used to inform regional and municipal government decisions regarding zoning and development permit applications.

- It is recommended that all land owners in the region cooperate to reduce nitrate loading from agricultural practices. Guidelines for environmentally sound practices for using, storing and

managing agricultural wastes and by-products are discussed in the Agricultural Waste Control Regulation (AWCR).

- It is recommended that samples of septic sewage wastewater be collected from several of the local septic disposal systems and analyzed for nitrate nitrogen and oxygen isotopes. These isotope data could potentially be used as a "fingerprint" for septic discharges in the aquifer and compared with currently available isotope data obtained from the local groundwater supply and monitoring wells.

## 6. REFERENCES

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3. A complete assessment of all possible conditions or circumstances that may exist at the Site or within the Study Area referenced, has not been undertaken. Therefore, if a service is not expressly indicated, it has not been provided and if a matter is not addressed, no determination has been made by Western Water Associates Ltd. in regards to it.
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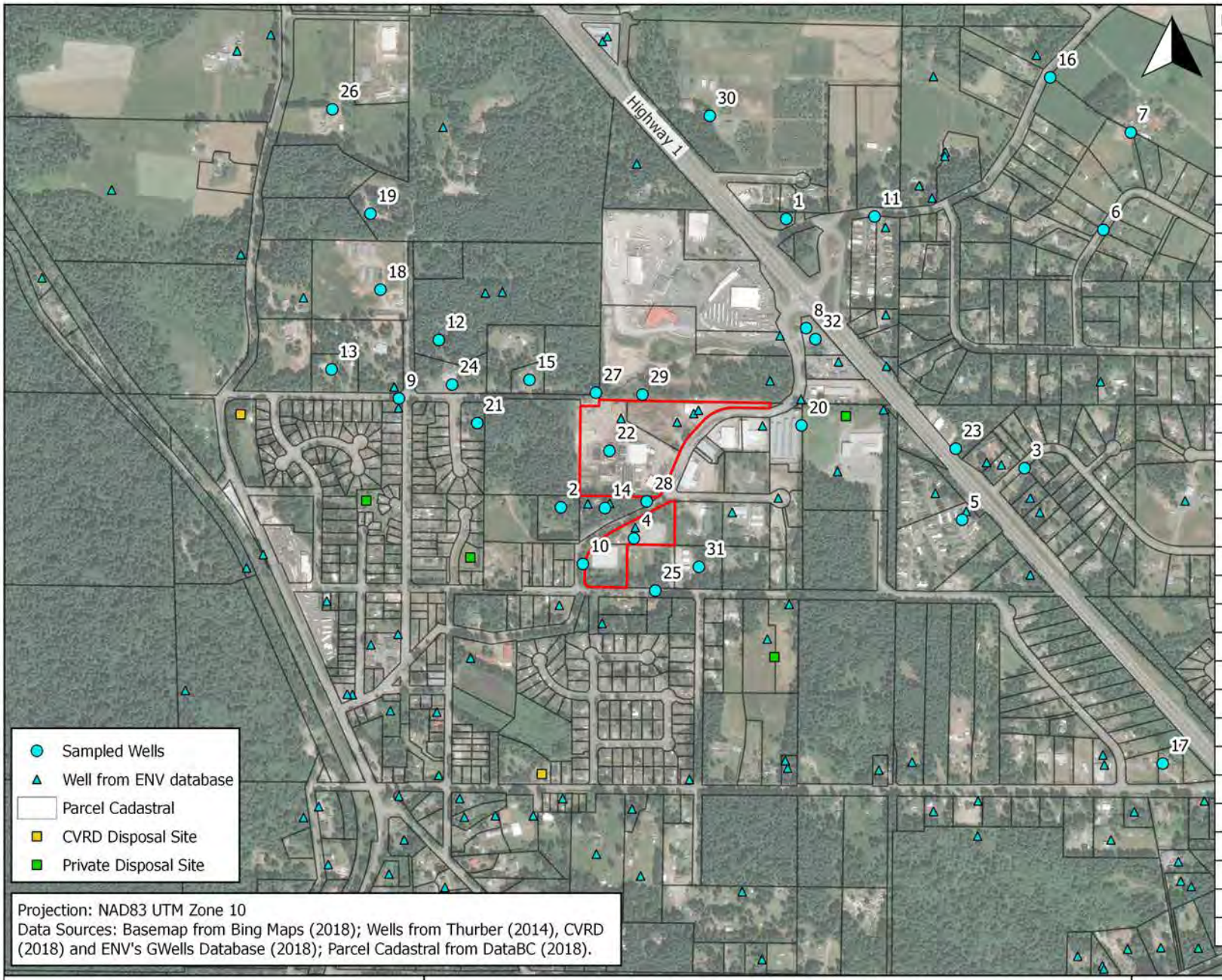
# Appendix A

Fisher Road GW Investigation Data Review
Site Plans and Cross Sections (Figures 1 to 4, and Figure 12)




| Number | Well Tag | Address |
|---|---|---|
| 1 | 14048 | - |
| 2 | 18686 | 1395 Fisher |
| 3 | 23811 | 3638 Vanland |
| 4 | 24510 | 1360 Fisher |
| 5 | 28425 | - |
| 6 | 40931 | - |
| 7 | 41479 | - |
| 8 | 47362 | 1310 Fisher |
| 9 | 54090 | - |
| 10 | 54123 | 1375 Fairfield |
| 11 | 54552 | 1260 Fisher |
| 12 | 55895 | 3713 Holland |
| 13 | 64013 | 1491 Gallier |
| 14 | 64066 | 1375 Fisher |
| 15 | 68617 | 1415 Gallier |
| 16 | 74681 | - |
| 17 | 85230 | 1135 Hutchinson |
| 18 | 88850 | 3720 Holland |
| 19 | 92643 | 3741 Holland |
| 20 | 102199 | 1334 Fisher |
| 21 | 102200 | 1442 Gallier |
| 22 | 102275 | 1355 Fisher |
| 23 | 104593 | 3649 Cedardale |
| 24 | 114629 | 1425 Gallier |
| 25 | 108347 | - |
| 26 | 114949 | 3791 Cobble Hill |
| 27 | 115138 | - |
| 28 | 115140 | - |
| 29 | 115141 | - |
| 30 | - | - |
| 31 | - | 1353 Fairfield |
| 32 | - | 1309 Fisher |

**Fisher Road GW Investigation Data Review**

TITLE **Figure 1:** Site Overview

0 100 200 300 400 m

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| | | | |
|---|---|---|---|
| DRAWN T.Sivak | DATE November 29, 2018 | PROJECT NO. 18-052-01 | |
| CHECKED | SCALE See Figure | DWG NO. | |
| REVIEWED | FILE NO. | FIGURE VERSION NO. | |


| ID | Well Tag | Address | Comment |
|---|---|---|---|
| 1 | 14048 | - | - |
| 2 | 18686 | 1395 Fisher | - |
| 4 | 24510 | 1360 Fisher | Gamboa Greenhouse Well |
| 5 | 28425 | - | - |
| 8 | 47362 | 1310 Fisher | - |
| 9 | 54090 | - | - |
| 10 | 54123 | 1375 Fairfield | - |
| 11 | 54552 | 1260 Fisher | - |
| 12 | 55895 | 3713 Holland | - |
| 13 | 64013 | 1491 Gallier | - |
| 14 | 64066 | 1375 Fisher | - |
| 15 | 68617 | 1415 Gallier | - |
| 18 | 88850 | 3720 Holland | - |
| 19 | 92643 | 3741 Holland | - |
| 20 | 102199 | 1334 Fisher | - |
| 21 | 102200 | 1442 Gallier | - |
| 22 | 102275 | 1355 Fisher | Fisher Rd Recycling Well |
| 23 | 104593 | 3649 Cedardale | - |
| 24 | 114629 | 1425 Gallier | - |
| 25 | 108347 | - | CVRD13-4 |
| 27 | 115138 | - | CVRD12-1 |
| 28 | 115140 | - | CVRD12-2 |
| 29 | 115141 | - | CVRD12-3 |
| 31 | - | 1353 Fairfield | - |
| 32 | - | 1309 Fisher | |

- Wells sampled by CVRD
- Wells from ENV's GWELLS database
- CVRD Municipal Disposal Field
- Private Septic Disposal Field
- Parcel Cadastral

Notes:
1) Nitrate concentrations depicted are most recent sample result compiled in tjs_18-052-01_WQ Summary_Oct_2018_Thurber Edits.xlsx.
2) Orange highlighed and bolded labels indicate groundwater samples exceed CSR DW standards for nitrate (10 mg/L).
3) White labels indicate groundwater sample result is below CSR DW standards for nitrate.
4) Map projection UTM NAD83 Zone 10

**Fisher Road Groundwater Investigation**

western water ASSOCIATES LTD

TITLE **Figure 2: Nitrate Concentrations in Fisher Road Wells**

| | | | |
|---|---|---|---|
| DRAWN T.Sivak | DATE November 29, 2018 | PROJECT NO. 18-052-01 |
| CHECKED | SCALE See Figure | DWG NO. |
| REVIEVED | FILE NO. | FIGURE VERSION NO. |

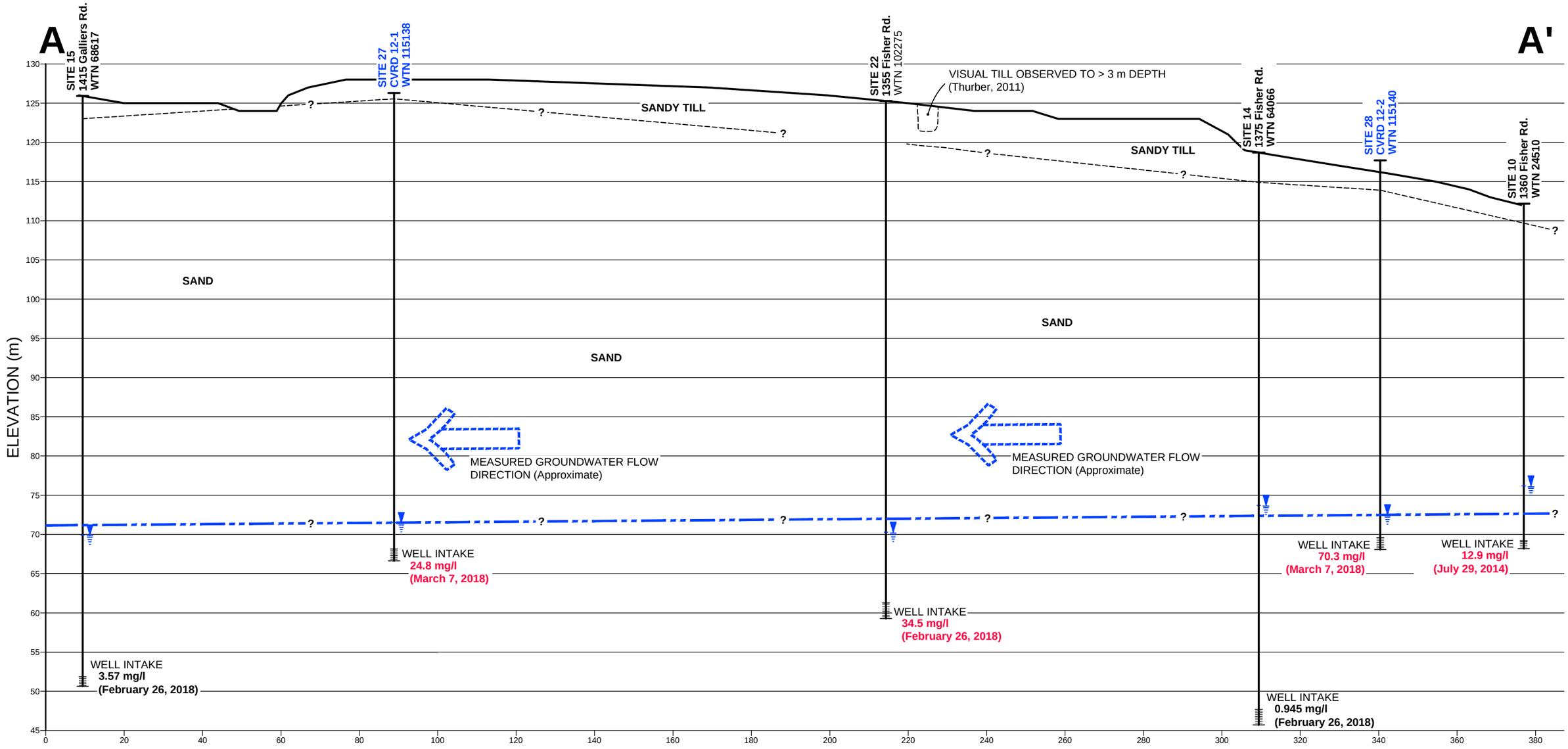
0 100 200 300 m

Well detail:
Site #
Sample Date (mm/dd/yyyy)
Nitrate concentration (mg/L)

Data Sources: Parcel cadastral from DataBC (2018); satelite imagery from Bing Satelite (2018)

# FISHER ROAD GROUNDWATER MONITORING
## SECTION A - A'

SCALE: AS SHOWN




**NOTES:**

1. The most recent available nitrate concentations are shown and the sampling date. Nitrate concentrations exceeding 10 mg/l are shown in red.
2. Topography obtained from 1 m contour data provided by the C.V.R.D.
3. Well and geological information obtained from driller's logs.
4. Surveyed well elevations for CVRD 12-1 and CVRD 12-2 provided by Kenyon Wilson, B.C.L.S.
5. Groundwater elevation shown based on measurements obtained at CVRD 12-1 and CVRD 12-2 on September 17, 2012. Groundwater elevations shown in the drinking wells were the drillers estimates at the time of drilling.

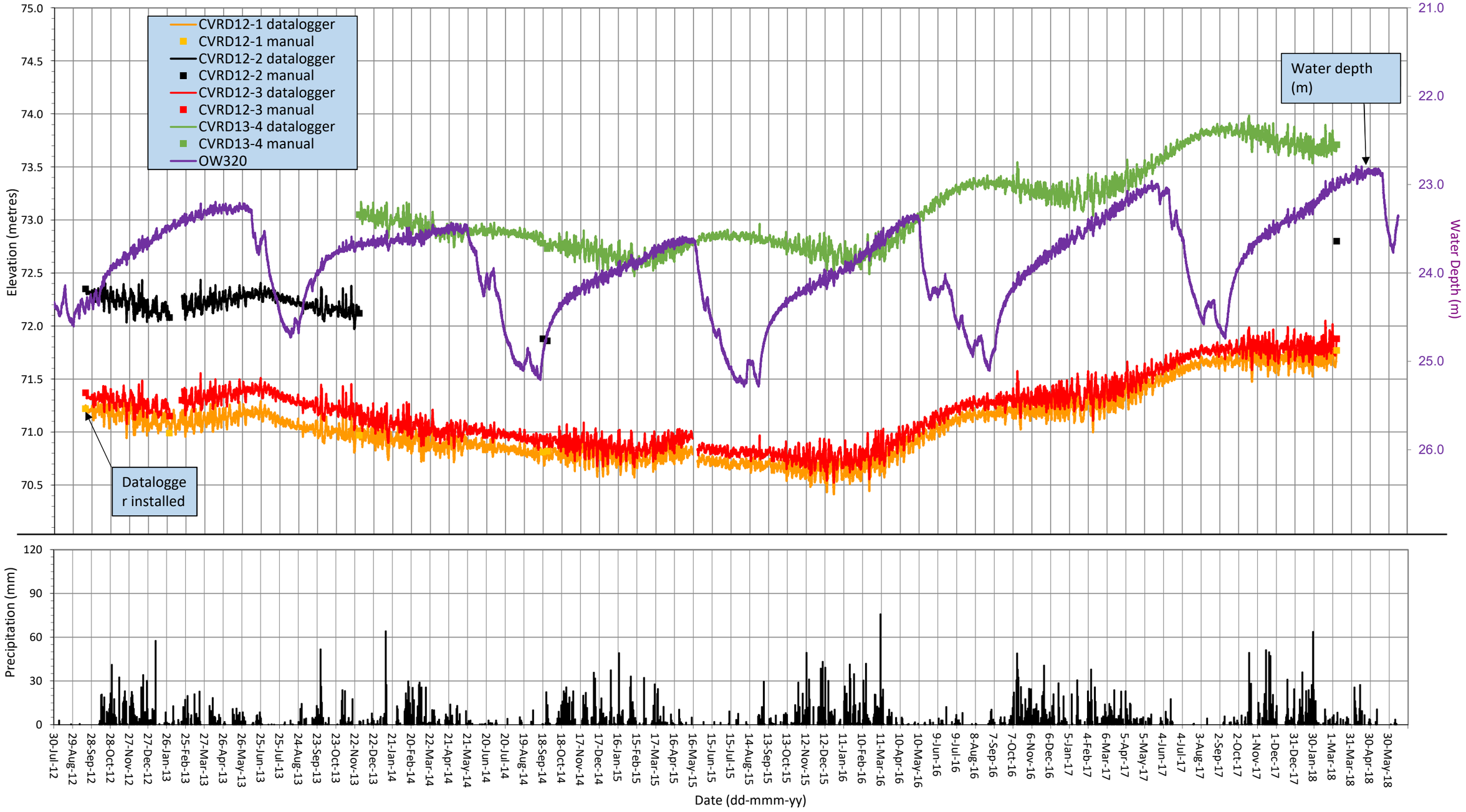
VERTICAL: 1:500 — SCALE 1:500

HORIZONTAL: 1:1000 — SCALE 1:1000

**FIGURE 3**

Client: Cowichan Valley Regional Distict c/o Western Water Associates Ltd.
File No.: 22743
E-File: 22743-CAD001.dwg

Date: October 3, 2018




TITLE

**Figure 4:** Fisher Road Groundwater Levels

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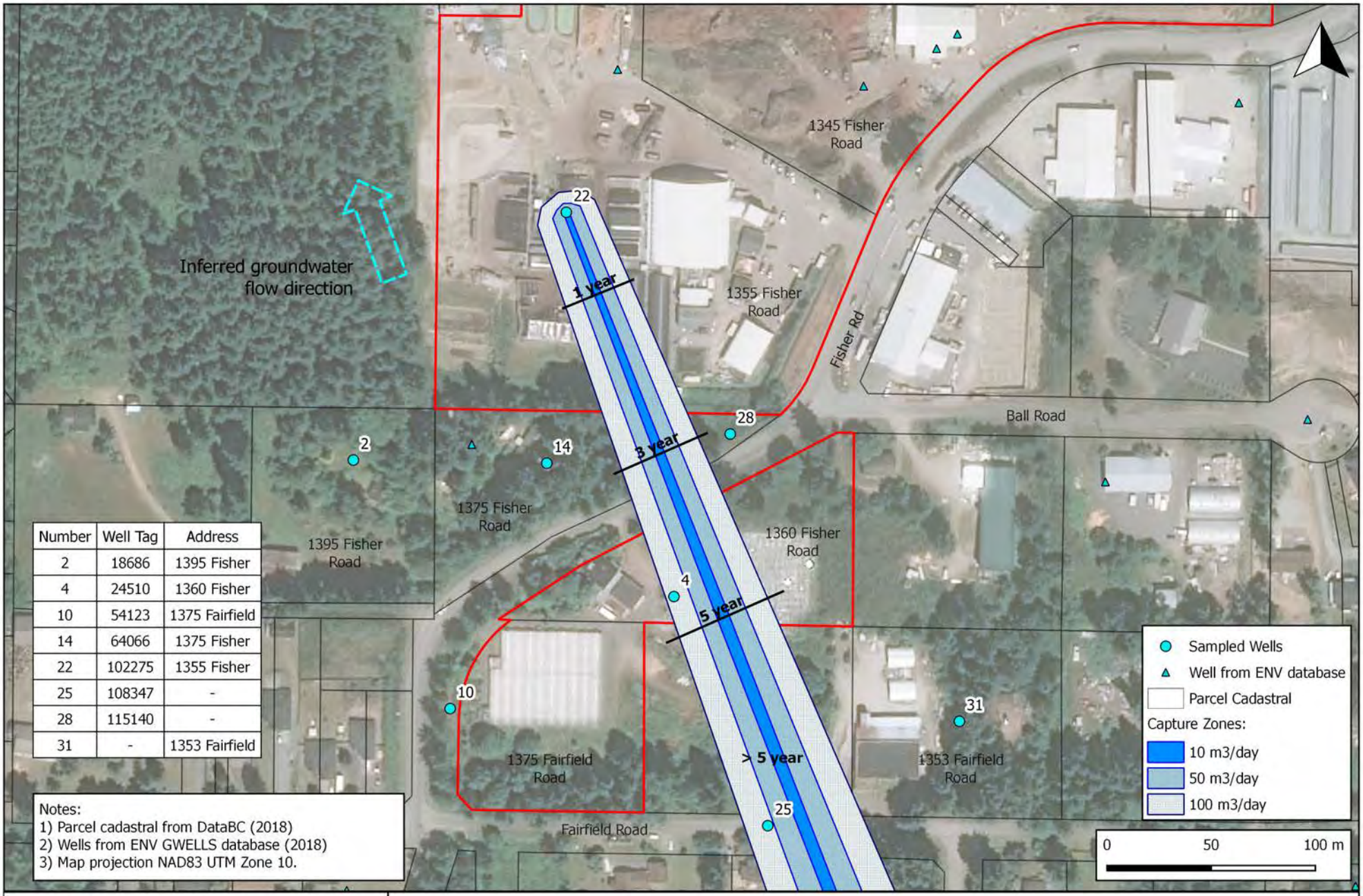
| | | | | | |
|---|---|---|---|---|---|
| DRAWN | CWP | DATE | October 17, 2018 | PROJECT NO. | 18-052-01 |
| CHECKED | | SCALE | | DWG. NO. | N/A |
| REVIEWED | | FILE NO. | | FIGURE VERSION NO. | |




| Number | Well Tag | Address |
|---|---|---|
| 2 | 18686 | 1395 Fisher |
| 4 | 24510 | 1360 Fisher |
| 10 | 54123 | 1375 Fairfield |
| 14 | 64066 | 1375 Fisher |
| 22 | 102275 | 1355 Fisher |
| 25 | 108347 | - |
| 28 | 115140 | - |
| 31 | - | 1353 Fairfield |

Notes:
1) Parcel cadastral from DataBC (2018)
2) Wells from ENV GWELLS database (2018)
3) Map projection NAD83 UTM Zone 10.

**Fisher Road GW Investigation Data Review**

TITLE **Figure 12:** 1355 Fisher Road Capture Zones

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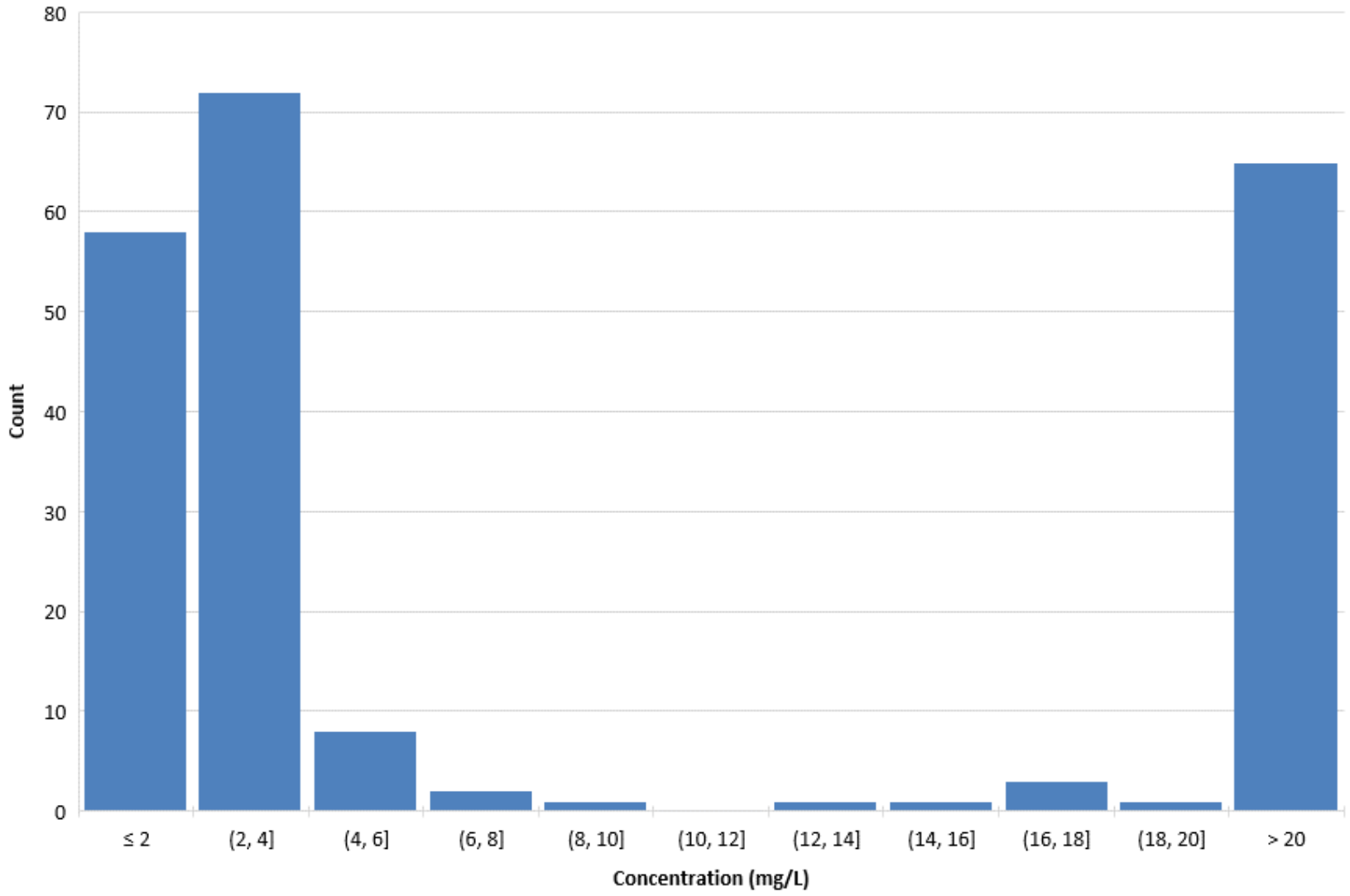
| | | | | | |
|---|---|---|---|---|---|
| DRAWN | T.Sivak | DATE | November 29, 2018 | PROJECT NO. | 18-052-01 |
| CHECKED | | SCALE | See Figure | DWG NO. | |
| REVIEVED | | FILE NO. | | FIGURE VERSION NO. | |

# Appendix B

Fisher Road GW Investigation Data Review
Nitrate Data Charts (Figures 5 to 11)




Fisher Road Groundwater Investigation Data Review

TITLE

**Figure 5 - Cobble Hill Aquifer Nitrate Concentration Histogram**

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| | | | | | |
|---|---|---|---|---|---|
| DRAWN | T.Sivak | DATE | October 15, 2018 | PROJECT NO. | 18-052-01 |
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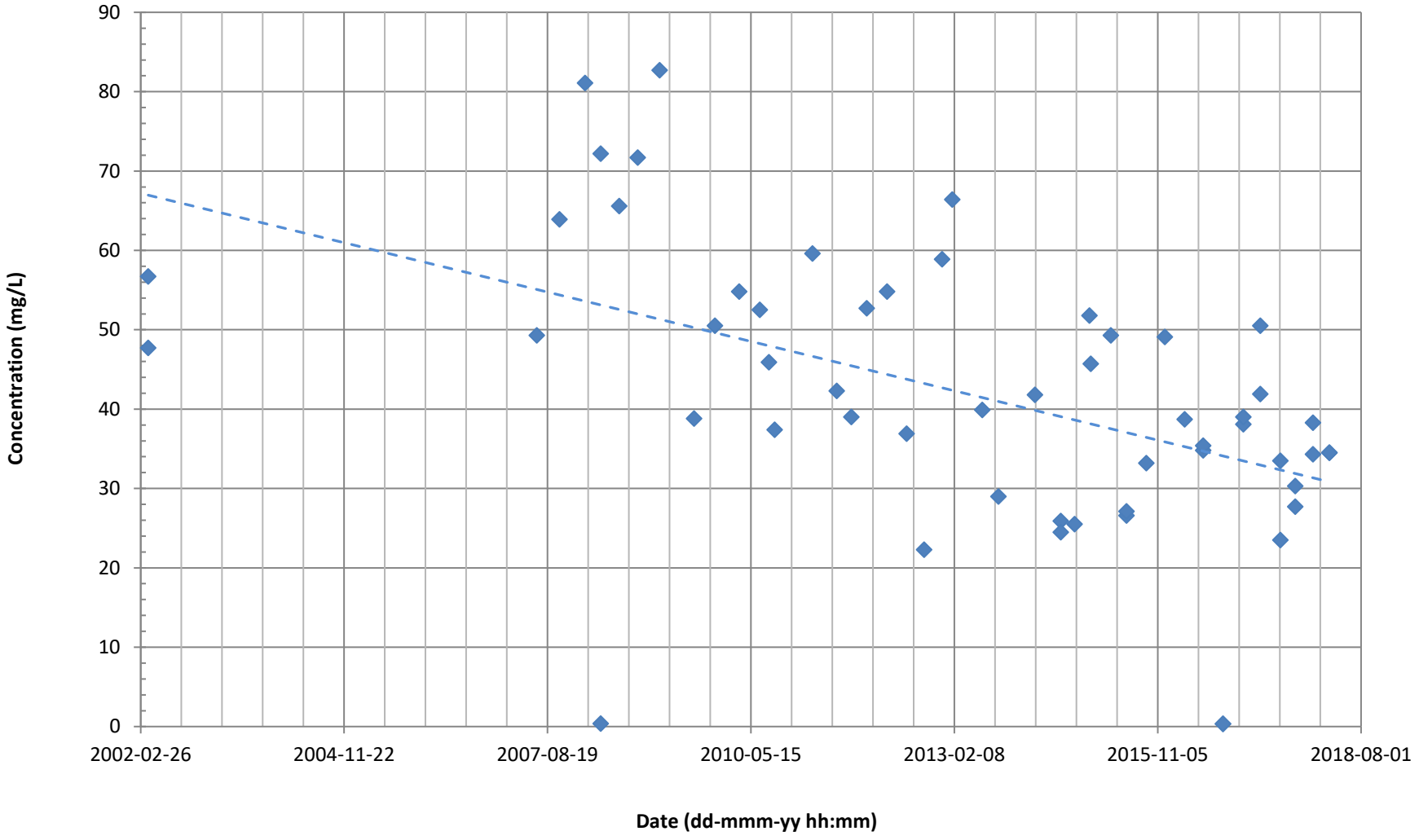


Fisher Road Groundwater Investigation Data Review

TITLE

**Figure 6 - 1355 Fisher Road Nitrate Concentration**

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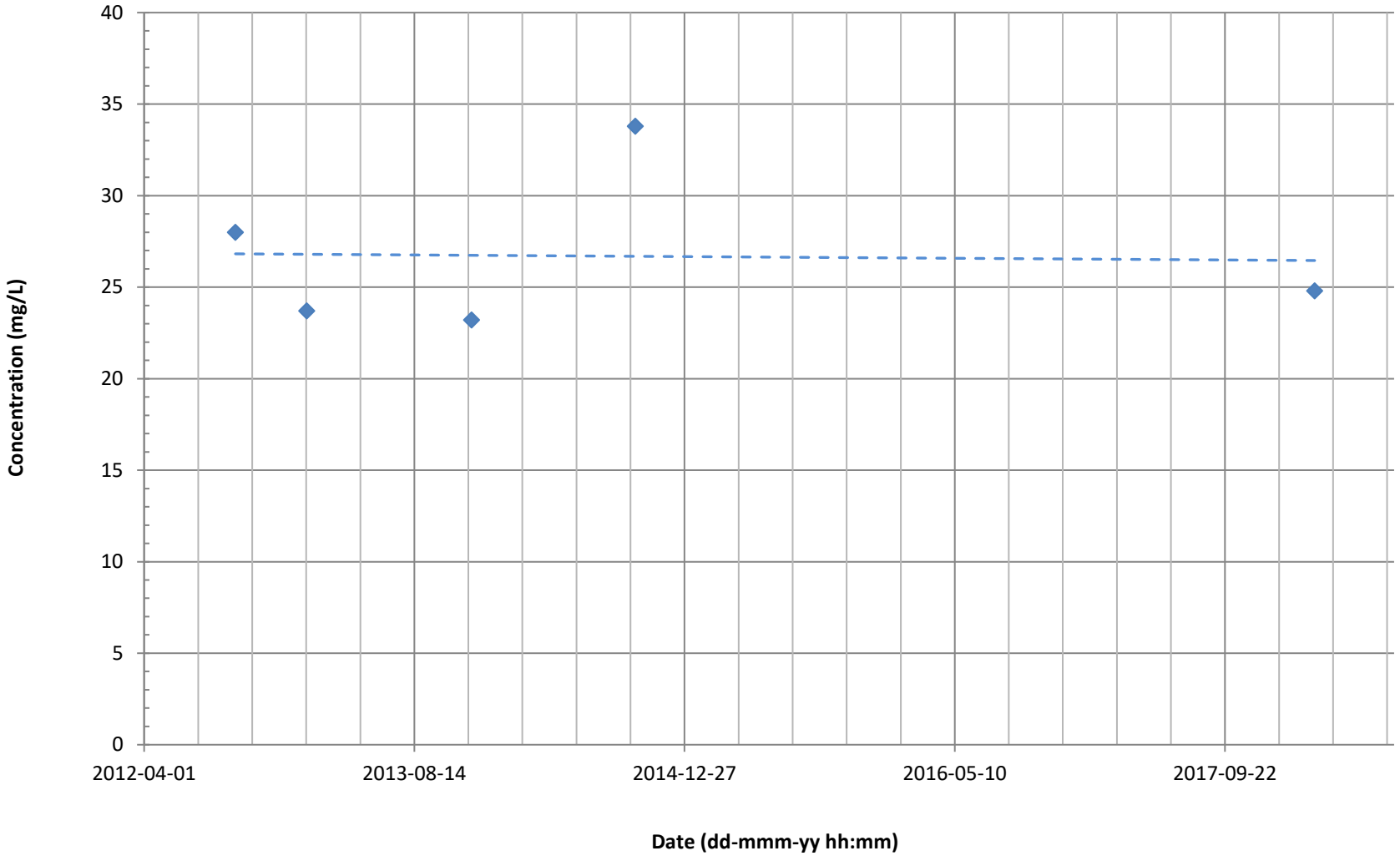
Consultants in Hydrogeology and Water Resources Management

| | | | | | |
|---|---|---|---|---|---|
| DRAWN | T.Sivak | DATE | October 15, 2018 | PROJECT NO. | 18-052-01 |
| CHECKED | | SCALE | N/A | DWG. NO. | N/A |
| REVIEWED | | FILE NO. | | FIGURE VERSION NO. | |




Fisher Road Groundwater Investigation Data Review

TITLE

**Figure 7 - CVRD12-1 Nitrate Concentration**

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| | | | | | |
|---|---|---|---|---|---|
| DRAWN | T.Sivak | DATE | October 15, 2018 | PROJECT NO. | 18-052-01 |
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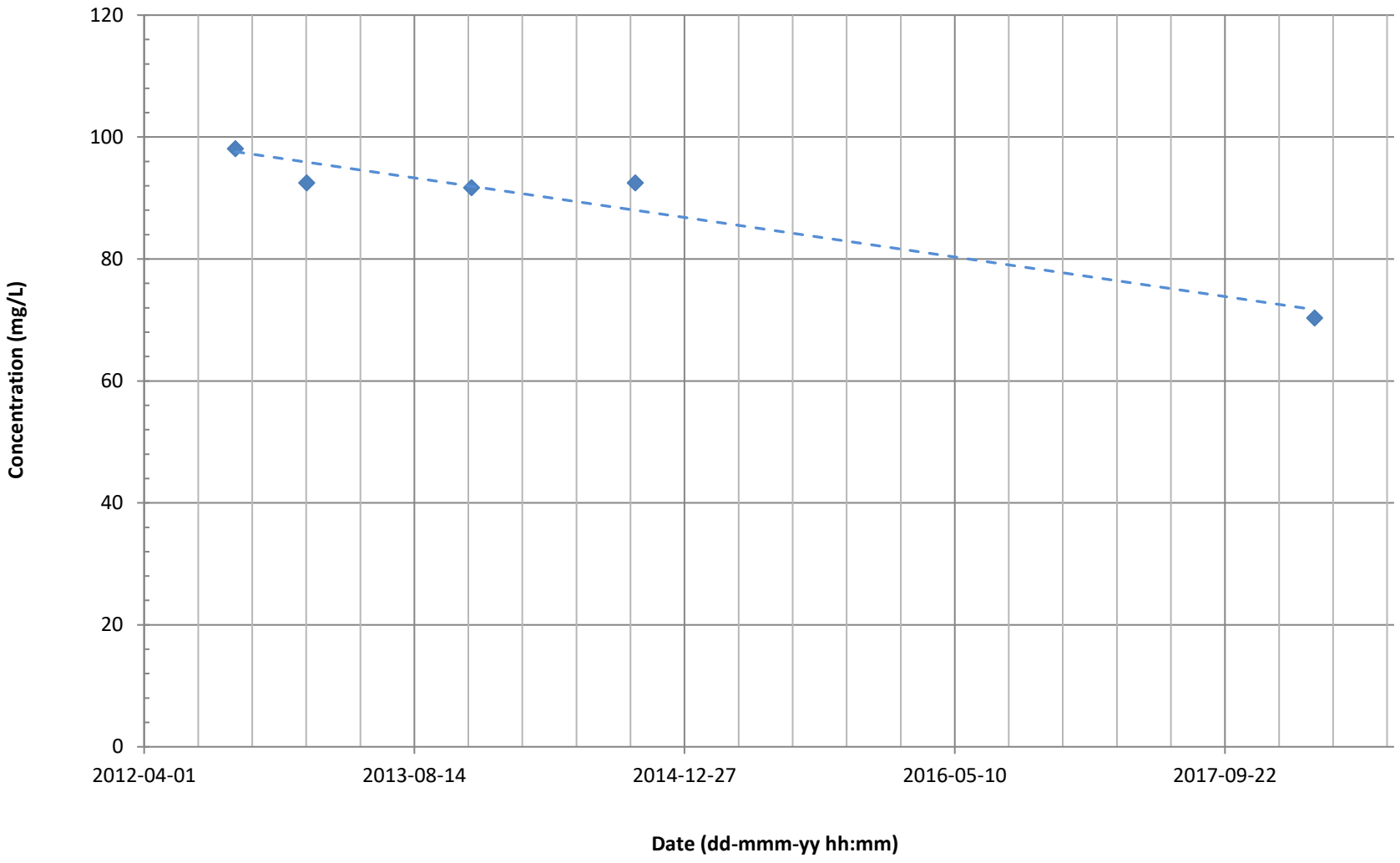
| REVIEWED | | FILE NO. | | FIGURE VERSION NO. | |




Fisher Road Groundwater Investigation Data Review

TITLE

**Figure 8 - CVRD12-2 Nitrate Concentration**

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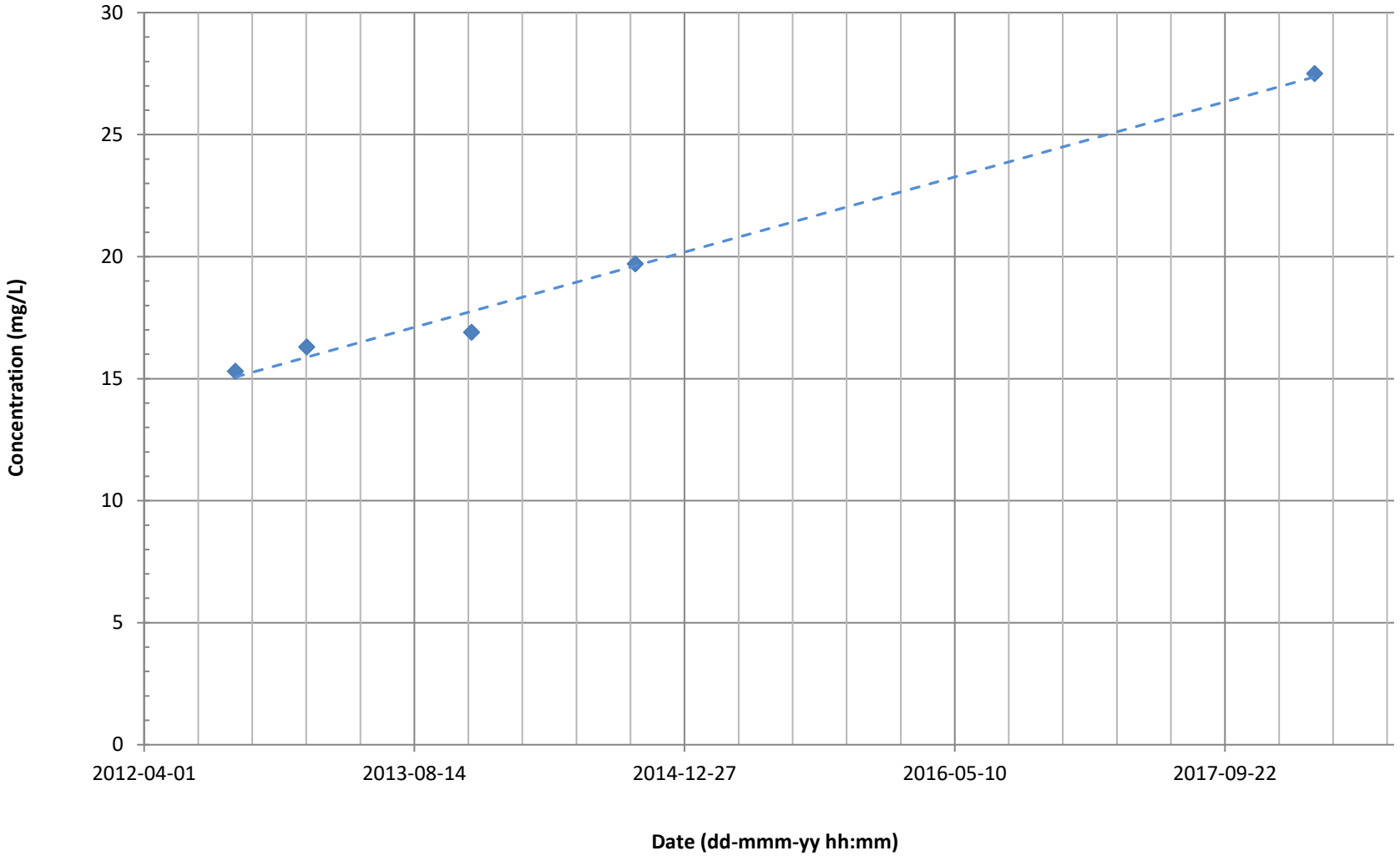
| | | | | | |
|---|---|---|---|---|---|
| DRAWN | T.Sivak | DATE | October 15, 2018 | PROJECT NO. | 18-052-01 |
| CHECKED | | SCALE | N/A | DWG. NO. | N/A |
| REVIEWED | | FILE NO. | | FIGURE VERSION NO. | |




Fisher Road Groundwater Investigation Data Review

TITLE

**Figure 9 - CVRD12-3 Nitrate Concentration**

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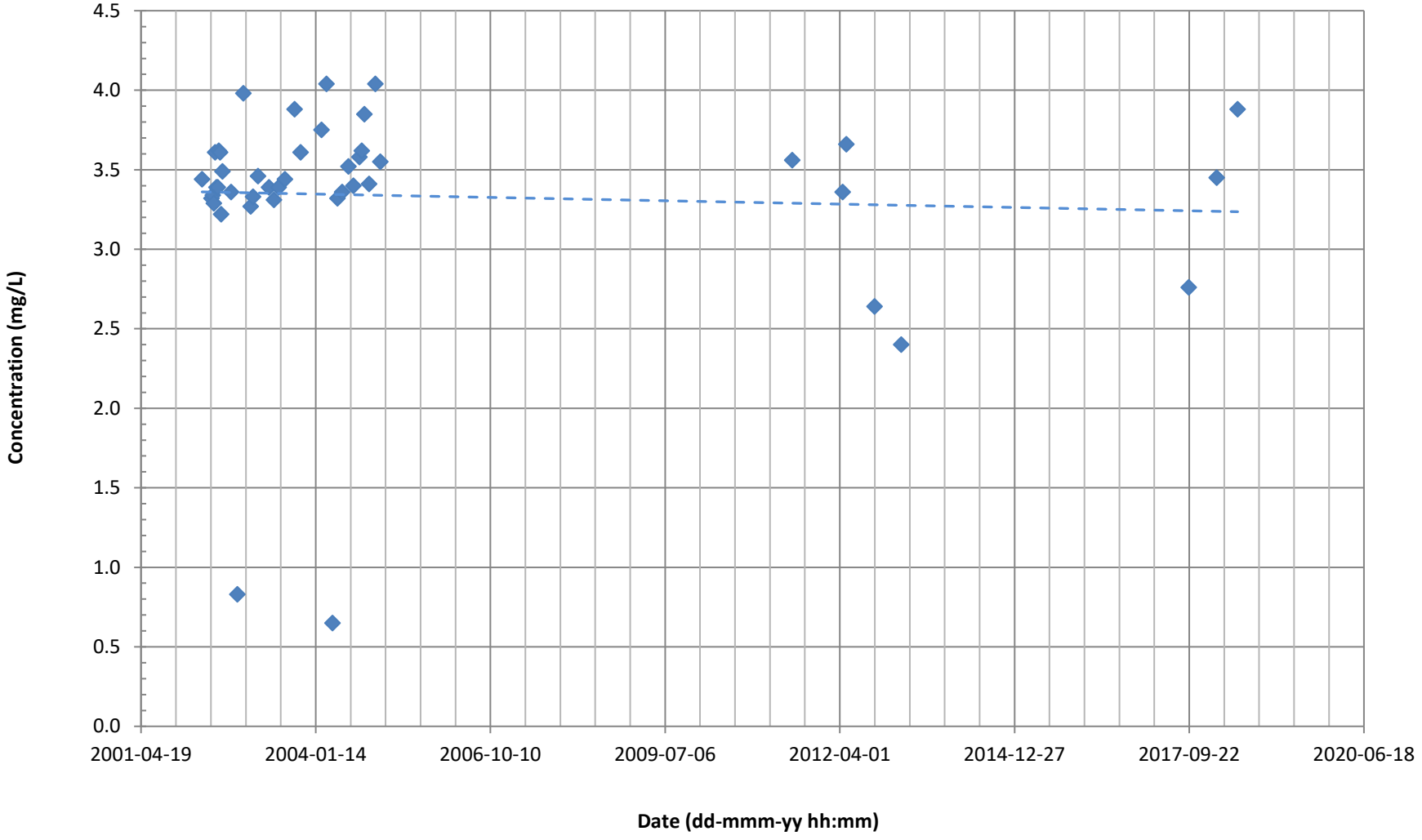
| | | | | | |
|---|---|---|---|---|---|
| DRAWN | T.Sivak | DATE | October 15, 2018 | PROJECT NO. | 18-052-01 |
| CHECKED | | SCALE | N/A | DWG. NO. | N/A |
| REVIEWED | | FILE NO. | | FIGURE VERSION NO. | |




Fisher Road Groundwater Investigation Data Review

TITLE

**Figure 10 - WTN 54090 Nitrate Concentration**

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Consultants in Hydrogeology and Water Resources Management

| | | | | | |
|---|---|---|---|---|---|
| DRAWN | T.Sivak | DATE | October 15, 2018 | PROJECT NO. | 18-052-01 |
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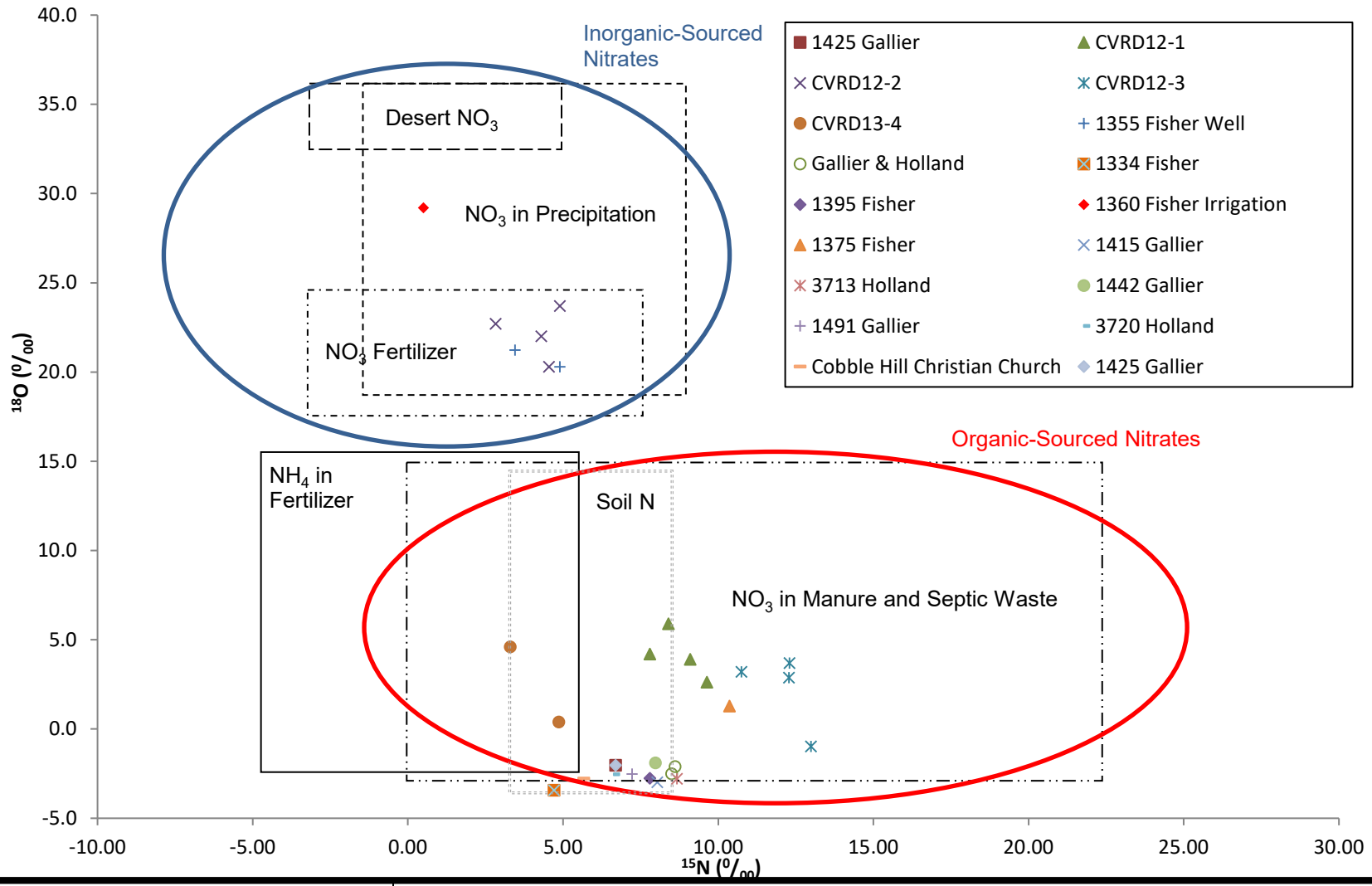


Fisher Road Groundwater Investigation Data Review

TITLE

**Figure 11 - Fisher Road NO3 Isotope Data**

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Consultants in Hydrogeology and Water Resources Management

| | | | | | |
|---|---|---|---|---|---|
| DRAWN | T.Sivak | DATE | October 15, 2018 | PROJECT NO. | 18-052-01 |
| CHECKED | | SCALE | N/A | DWG. NO. | N/A |
| REVIEWED | | FILE NO. | | FIGURE VERSION NO. | |


Groundwater Supply Development and Management

Source Water Assessment and Protection

Well Monitoring & Maintenance

Environmental & Water Quality Monitoring

Storm & Wastewater Disposal to Ground

Groundwater Modeling

Aquifer Test Design and Analysis

Geothermal / Geoexchange Systems

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