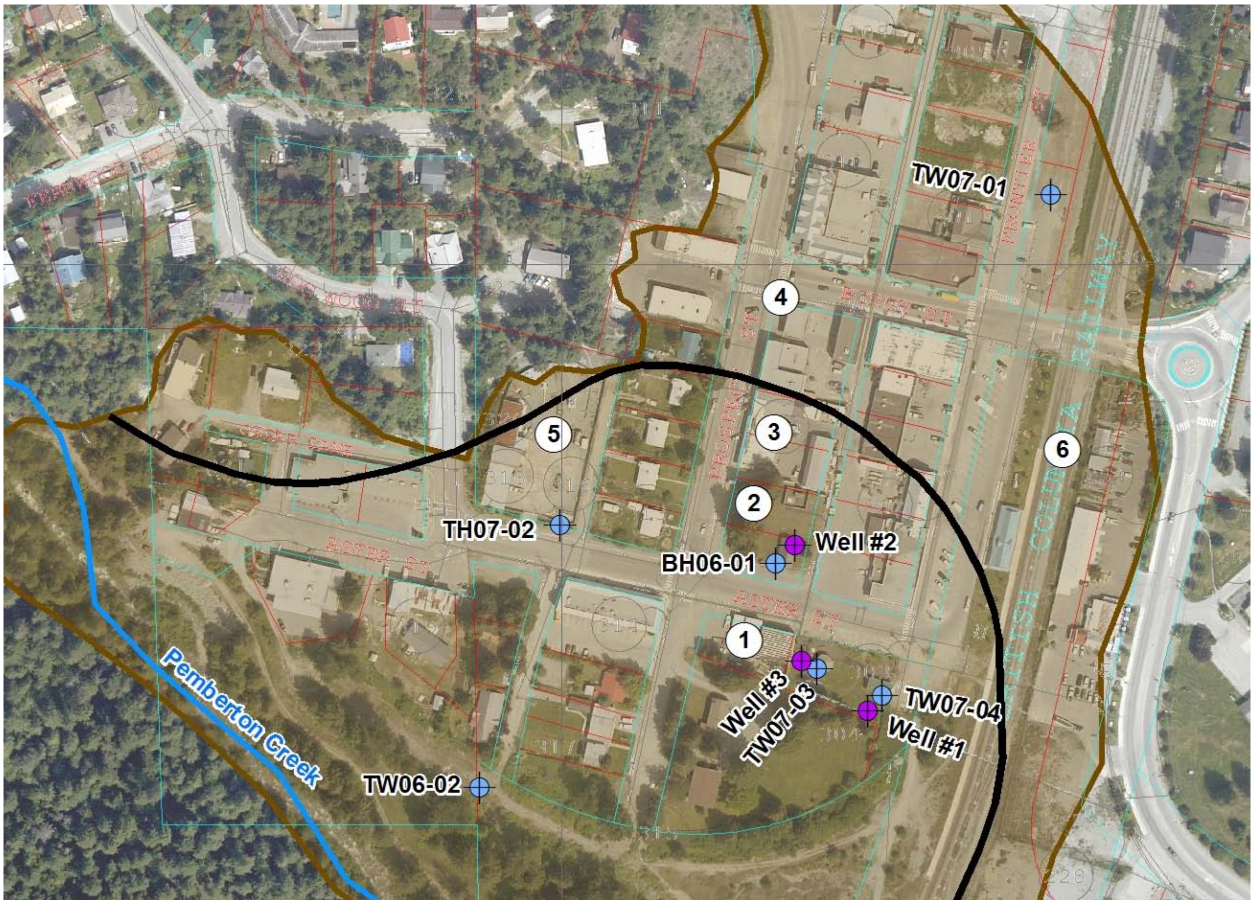
203 - 2902 West Broadway, Vancouver, BC, Canada V6K 2G8 • Tel: (604) 733-5930 • Fax: (604) 733-5931

Enterprise Geoscience Services Ltd.

Village of Pemberton
Hydrogeological Assessment For
Groundwater Protection Plan



Prepared by
Enterprise Geoscience Services Ltd.
Vancouver, BC

Project No. 12002 March 2012

EXECUTIVE SUMMARY

The Village of Pemberton uses groundwater pumped from an alluvial fan aquifer as its drinking water supply source. As a condition of its Permit to Operate the water system, the Village was required to develop a groundwater protection plan to protect the water source from contamination. This hydrogeological assessment was prepared in partial fulfillment of this requirement.

The Village water supply wells (Wells #1, #2 and #3) are screened in a semi-confined to unconfined sand and gravel aquifer (Pemberton Creek Fan Aquifer), between depths of 21 m to 46 m. The highly productive portion of the aquifer is limited to approximately 4 ha in area in the central portion of the fan in the downtown area of the Village. The aquifer is classified as being highly vulnerable to sources of surface contamination and is moderately to highly utilized for water supply.

The construction of the wells appears to meet all requirements of the Ground Water Protection Regulation with respect to surface sealing, well caps and covers, floodproofing and wellhead protection. We could not confirm the adequacy of the surface seal for Well #3 (drilled in 2008) because no construction log is available.

Wells #2 and #3 are the primary source wells with Well #1 used only as an emergency back up well. The performance of Well #1 has historically declined in spite of efforts to rehabilitate the well due to growth of iron bacteria. Current water demand ranges from about 22 L/s during the winter to a peak summer demand of 38 L/s.

The primary source of aquifer recharge is interpreted to be leakage from the bed of Pemberton Creek that flows across the southwest margin of the alluvial fan. Infiltration of snowmelt and precipitation, and discharge of groundwater from bedrock into the fan deposits are a secondary and much less significant source of recharge.

A small hydro feasibility study carried out for the Village examined alternatives for power generation on Pemberton Creek with one alternative intercepting a very significant portion of the creek flow in a penstock and diverting this to a powerhouse lower in elevation than the alluvial fan. It is concluded that this could seriously impact aquifer recharge and diminish the water available for pumping.

The water quality of the Pemberton Creek Fan Aquifer is a calcium-bicarbonate type with very low total dissolved solids typical for young, recently recharged groundwater. The groundwater is mildly acidic and somewhat corrosive for copper plumbing. Aside from its mildly acidic character, water quality from the two primary source wells is very good and meets Guidelines for Canadian Drinking Water Quality for all of the chemical and physical parameters analyzed. Well #1, utilized only on an emergency basis to meet fire flows, has elevated turbidity, iron and manganese due to iron bacteria growths that have been historically problematic. There is some evidence of slightly increased chloride concentrations in Well #2 that are probably due to storage of ploughed snow near the wellhead in Fougberg Park, although the concentrations are well below the drinking water quality guidelines.

The bacteriological water quality has been very good with the exception of some detections of total coliform in Well #3 during 2009, following commissioning of the well in 2008. Lack of any detections in 2010 and 2011 suggest the total coliform detections may have been the result of well commissioning, such as inadequate disinfection of the pump string or other downhole equipment.

Potential sources of contamination within and near the well capture zone and groundwater protection area include a tire shop, storage of ploughed snow near one of the wellheads, a commercial hardware store, a service station, a BC Hydro property where electrical transformers were formerly stored in a gravel yard, and the BC Rail mainline and an historical siding where rail cars were temporarily stored. The most significant concern is the tire shop, located immediately adjacent to the wellhead of Well #3, where parts washer solvents and other hazardous materials are stored.

An assessment of the risk of the water supply wells to pathogens such as Giardia and *Crytosporidium* originating from surface water or ground surface indicates the risk should be low, although this is subject to confirming an adequate surface seal for Well #3, a commitment by the Village not to store ploughed snow near the wellheads, and resolving a discrepancy in the interpreted travel time of seepage from Pemberton Creek to the wells based on hydrogeologic calculations of groundwater velocity and temperature measurements made in the water system.

The following recommendations are made with regard to groundwater protection measures for the Village of Pemberton water supply system and the Pemberton Creek Fan Aquifer:

i. Designate the groundwater protection zone as an environmentally sensitive area in the Villages' Official Community Plan;

ii. Do not commit to any small scale hydro generation project that would divert significant portions of the flows in Pemberton Creek from the fan area where the aquifer is recharged;

iii. Form a groundwater source protection planning committee that includes representation from businesses located in the well capture zone. Communicate key findings of this groundwater protection plan with management of businesses identified as having a potential to cause contamination of the aquifer.

iv. Commit to developing alternate locations for winter storage of ploughed snow away from wellheads;

v. Locate a copy of the construction log for Well #3 and confirm that the well has an adequate surface well seal in accordance with the Ground Water Protection Regulation;

vi. Measure and record temperature weekly from both primary source wells and Pemberton Creek for a period of one year. Have a qualified person review this to determine if there is a temperature signal propagated through the aquifer to the wells from the creek and assess the time of travel. Following this, review the "ground water at risk of pathogens" (GARP) and "ground water under direct influence of surface water" (GWUDI) risk classification;

vii. During 2012 and every three years thereafter, test the source wells for volatile organic compounds (VOCs) to assess the potential for contamination from hydrocarbon sources such as petroleum fuels and parts washer solvents;

viii. Have a qualified person plot and analyze historical water levels in both primary source wells every three years to determine if water levels remain stable year over year or are declining. Declining water levels can indicate decreasing well performance or an overdraft (overpumping) of the aquifer.

TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

1.0 INTRODUCTION

1.1 Background

The Village of Pemberton (Village) operates a wellfield to extract water from an aquifer for potable water supply. The wellfield consists of two primary wells and a backup well used in emergency purposes that supplies a population of approximately 2,339 (BC Stats, 2008). The Vancouver Coastal Health Authority (VCH) issues the Permit to Operate the water system and has required that the Village prepare a groundwater protection plan (GPP) for their review as a condition of the Permit. This report has been prepared in partial fulfillment of this requirement.

1.2 Groundwater Protection Plan Scope

A GPP is used to provide guidance on groundwater source protection which is one part of a multibarrier approach, involving monitoring, water system maintenance, operator training, treatment and emergency response planning, in providing safe drinking water. Source water protection is a cornerstone in safeguarding water supply as it is invariably less expensive to protect source water than to respond to emergencies in the event of contamination, develop new water sources or provide additional treatment.

These plans are developed by a committee which has representation from stakeholders involved in the aquifer, government agencies involved with regulating industrial and resource activities in the aquifer recharge zone and industries active in the wellfield capture zone. This report provides a description of the aquifer, defines the wellfield capture zone, identifies potential sources of contamination, defines a groundwater protection area, and provides recommendations for protection of the groundwater source.

2.0 SCOPE OF WORK

Preparation of this GPP involved the following project tasks:

- Meetings with Village staff to obtain information about the water system and with the VCH Drinking Water Officer to discuss preliminary findings;

- Site reconnaissance to examine the source water wells and surrounding land use activities;

- Review of available reports and information on the construction, testing and monitoring of the source wells as well as information about local aquifers and surface waters;

- Mapping of the boundaries of the Pemberton Creek Fan Aquifer, the source aquifer for the Village water system;

- Identifying the well capture zones based on the mapping conducted to asses the aquifer boundaries and results of pumping tests conducted following construction of the source wells;

- Mapping of the groundwater protection area based on well capture zones, land use activities and areas in the aquifer that may potentially be suitable for future source wells if required; and,

- Incorporating all information into this hydrogeological assessment.

A number of sources of information were reviewed in the preparation of this GPP as listed in the references. These included previous reports by Pacific Hydrology Consultants Ltd (1992 and 1997), Golder Associates (2004, 2006a, 2006b, 2007a, 2007b), Associated Engineering Ltd (2003), Precision Service and Pumps Inc. (2002 and 2003), Coast Garibaldi Health (2000 and 2003) and EarthTech (2008), relating to the investigation, development, assessment and treatment of the current groundwater supply for the Village. Air photograph coverage of the Pemberton Valley was reviewed, along with topographic and cadastral maps, the Villages' Official Community Plan, and a feasibility study to develop a small-scale hydro project on Pemberton Creek (Summit Power Management Inc., 2007). Chemical and bacteriological water quality data obtained from source well sampling were also reviewed together with monitoring data on well flow rates and water levels collected using a SCADA system and measurements of water pH and temperature collected in the distribution system at the Municipal Hall.

3.0 PHYSIOGRAPHIC DESCRIPTION

3.1 Location and Setting

The Village of Pemberton is located in the Pemberton Valley, approximately 150 km north of Vancouver and 30 km north of Whistler, BC. The municipal boundaries are located to the west of the Lillooet River and north of the Green River as shown on Figure 1 (following text of report). The Villages' source wells and the downtown area of Pemberton are situated on an alluvial fan where Pemberton Creek flows into the Pemberton Valley. Elevations across the fan range from about 215 to 225 m. The Village is located within a floodplain and dykes are constructed to control flooding on Pemberton Creek and Lillooet River.

3.2 Pemberton Creek Watershed

Pemberton Creek is interpreted to be the primary source of recharge for the aquifer supplying the Village water system and is therefore of great interest in understanding and protecting the groundwater resource. Much of the information concerning the watershed comes from a report commissioned by the Village in 2007 to study the feasibility of developing a small hydroelectric project on Pemberton Creek (Summit Power Management Inc., 2007).

Pemberton Creek rises at the Ipsoot Glacier approximately 10 km west of the Village (Figure 1). The catchment area above the Village is just over 31 km^2. Elevations in the watershed range from approximately 210 m at the confluence with Lillooet River to 2438 m at the peak of Ipsoot Mountain. The primary land use activity in the watershed is forestry.

Flows in Pemberton Creek are controlled strongly by melting and freezing of the glacier with low flows in the winter months and peak flows during May to August. Mean monthly flows and mean monthly air temperatures are summarized in Table 1 (following text of report). Minimum flows range from approximately 0.4 to 0.6 m^3/s during November to January when mean air temperatures are below freezing and peak flows range from approximately 3.0 to 3.3 m^3/s during May to July (Table 1).

Prior to developing a groundwater supply in 1992, the Village obtained its water supply from an intake on Pemberton Creek. The small hydro feasibility study indicates there are two water licenses issued to the Village and one license issued to the Squamish Lillooet Regional District authorizing withdrawals from Pemberton Creek as summarized in Table 2.

Table 2 – Water Licenses on Pemberton Creek

Purpose	Quantity (L/s)	Licensee	License No.	Priority Date (yyyy-mm-dd)
Waterworks Local Auth.	3.07	Village of Pemberton	C026463	1959-04-14
Waterworks Local Auth.	4.38	Squamish Lillooet Regional District	CO29836	1963-12-31
Land Improvement	56.6	Village of Pemberton	CO61785	1985-04-18

The small hydro feasibility study considered various options for intake structures on the upper reaches of Pemberton Creek and conveying water by penstocks to a powerhouse located lower in the watershed. The two locations considered for the intake are shown relative to the Village municipal boundaries and Ipsoot Mountain on Figure 2. The study indicated that a significant proportion of the total flow in Pemberton Creek would be diverted (in the order of 2 to 3 m^3/s) to generate power. Two powerhouse alternatives were considered: Alternative 1 located above the Village at an elevation of approximately 260 m and Alternative 2 with a powerhouse located near the base of the alluvial fan at an elevation of approximately 225 m. Under Alternative 2, a very significant proportion of the flow in Pemberton Creek over the fan would be reduced, thus reducing the recharge to the aquifer and reducing the availability of groundwater for pumping. **Any proposal that would divert water out of Pemberton Creek over the Pemberton Creek fan could significantly diminish the recharge to the aquifer and seriously impact the Villages' water source.**

3.3 Geology

The bedrock and surficial geology of the Pemberton area is described by the Geologic Survey of Canada (Roderick and Hutchison, 1973), Holm et. al. (2004) and Simpson et. al. (2006). The bedrock forming the mountains of the Pemberton Creek valley and surrounding area are mapped as quartz diorite mainly of Mesozoic age.

The surficial deposits infilling the Pemberton Valley consist of coarser-grained alluvium and finer-grained overbank deposits from the Lillooet River. There have also been a number of volcanic debris flows originating from the Mount Meager Volcanic Complex that have been partly responsible for infilling of the Pemberton Valley and may be related to the generally acidic soils in the valley. In the downtown area of Pemberton, the alluvial fan of Pemberton Creek has formed overlying bedrock and the older alluvial, overbank and volcanic debris flow deposits infilling the valley.

3.4 Regional Hydrogeology

The BC Ministry of Environment (MOE) has completed a program of mapping and classifying aquifers throughout much of the province, including the Pemberton Valley. The mapping identifies the boundaries of the aquifers and they are classified according to their level of development or utilization (light, moderate, heavy) and their vulnerability (low, moderate, high). The vulnerability refers to how susceptible an aquifer is to contamination from sources at or near the ground surface. For example, a shallow sand and gravel aquifer with a high water table would be highly vulnerable to contamination whereas a deep aquifer covered by a thick confining layer of clay would have low vulnerability.

MOE mapping for the Pemberton area has identified one significant sand and gravel aquifer that includes the area of the Pemberton Creek alluvial fan and all valley bottom lands surrounding the Lillooet River. The aquifer is designated as Aquifer No. 0326 and is classified as IIIA meaning it has a low level of development and is highly vulnerable. According to Pacific Hydrology (1992) and Russell Mack (per. comm.), groundwater quality in the main aquifer infilling the Pemberton Valley is typically characterized by elevated iron concentrations.

4.0 AQUIFER CHARACTERIZATION

4.1 Physical Description

The alluvial fan of Pemberton Creek formed as sediments (cobbles, gravel, sand and silt) are deposited by the creek as the gradient of the creek decreases where it descends from the steeper upper reaches into the Pemberton Valley. The creek gradient decreases from a slope of approximately 18% in the canyon above the Village to less than 1% across the fan.

Aerial photographs were used to map the boundaries of the alluvial fan which is shown on Figure 3. The alluvial fan is interpreted to overlie bedrock along the apex and flanks of the fan, and older alluvial sediments deposited by the Lillooet River in the base of the Pemberton Valley in the eastern, downslope margin. In this report, the saturated alluvial fan deposits are referred to as the Pemberton Creek Fan Aquifer to distinguish the aquifer from the older underlying alluvial sediments deposited by the Lillooet River. Alluvial fan deposits on steep creek systems are typically heterogeneous varying in grain size both laterally and vertically due to seasonal flooding and changes in the creek path over the fan throughout the depositional history.

The entire area of the fan is approximately 17.3 ha, although only the central portion appears suitable for development of high capacity wells. Hydrogeologic section AA'extending from southwest to northeast across the fan is shown on Figure 4. The section line is shown in plan on Figure 3. Test drilling further upslope from the production wells (test holes TW06-02 and TH07-02) confirm that the aquifer sediments are either "cemented" and have lower permeability, or shallower bedrock depth precludes construction of a high capacity well. Farther east, near the toe of the alluvial fan (test hole TW07-01), sediments were finer grained (fine to medium sand and silty sand). The highly productive area of the Pemberton Creek Fan Aquifer is outlined on Figure 3, although this area is not well defined to the east and south. In the vicinity of the Villages' wellfield, the alluvial sediments are about 40 to 45 m in thickness. **The highly productive area of the Pemberton Creek Fan Aquifer is situated in the central portion of the fan occupying an area of about 4 ha or 23 % of the entire 17.3 ha of the alluvial fan.**

4.2 History of Aquifer Development

The Village formerly obtained water supply from an intake on Pemberton Creek and converted to a groundwater system when the first production well was drilled in 1992. This well has been previously referred to as Well 1-92 and more recently as Well #1 and we use this later terminology throughout this report. Well #1 was drilled at a diameter of 200 mm to a depth of 29 m and had a reported yield on the driller's log of 28.8 L/s. The well is located in Pioneer Park south of Aster Street and adjacent to the Villages' office (Figure 3).

The yield of Well #1 decreased over time and a second well (Well 2-97 referred to as Well #2) was drilled in 1997. This was preceded by a test hole drilled in 1996 (BH06-01, Figure 3). Well #2 was drilled at a diameter of 300 mm to a depth of 41.8 m and had a reported yield of 76.0 L/s. Well #2 is located approximately 80 m northwest of Well #1, north of Aster Street and east of Prospect Street.

Due to continued poor performance of Well #1, a suitable backup well for Well #2 was recommended by the Villages' consultants and a series of test holes were drilled in 2006 and 2007. Poor subsurface conditions for construction of a high capacity well were encountered to the west, southwest and northeast of Well #1 and Well #2 and a decision was made to install a third production well (Well #3) in Pioneer Park in close proximity to Well #1 but at greater depth in the aquifer. Available information indicates Well #3 was drilled in 2008 at a diameter of 200 mm to a depth of 46 m and has a reported yield of about 50 L/s.

4.3 Aquifer Recharge

Three sources of recharge have been identified for the Pemberton Creek Fan Aquifer which are listed below in the interpreted decreasing order of significance:

i. Leakage from Pemberton Creek;

ii. Infiltration of snowmelt and precipitation over the surface of the fan; and,

iii. Discharge of groundwater contained in bedrock underlying the base and sides of the fan

Leakage from Pemberton Creek into the alluvial fan deposits is interpreted to be the primary source of aquifer recharge, replenishing the water pumped for water supply needs. Local infiltration of snowmelt and direct precipitation on the fan are also expected to contribute to recharge, but to a much lesser extent. Lastly, groundwater present in bedrock likely discharge into the saturated alluvial fan deposits, although this is interpreted to have only a very minor contribution to the overall water balance of the Pemberton Creek Fan Aquifer. This interpretation is based in part on our previous experience with other alluvial fan aquifers in the region and on monitoring data collected by the Village.

The alluvial fans of Britannia Creek and Deeks Creek located between Squamish and Horseshoe Bay were studied extensively for water supply involving test holes, pumping tests and computer models. In the case of the Britannia Creek alluvial fan, it was determined that 87% of the aquifer recharge came from leakage from Britannia Creek, with the remainder coming from direct precipitation/snowmelt on the surface of the fan and runoff from adjacent sideslopes.

Water temperature data collected by the Village from within the distribution system also provides evidence to indicate the aquifer is recharged by Pemberton Creek. Monitoring data for 2011 including pumping rate and water levels in the two primary source wells, and water pH and temperature measured within the distribution system at the Village office are presented in Appendix A. Water temperature increases from approximately 8 to 10 ^{0}C during winter peaking at 18 to 20 ^{0}C in August and early September, with temperatures descending beyond mid September. This is interpreted to be a temperature signature caused as warming water from Pemberton Creek moves through the aquifer towards the pumping wells. Review of 2011 temperature data for Pemberton Airport indicates that there is a very short lag time between decreasing air temperatures and decreasing water temperatures during September, 2011. Assuming that it is correct that water temperature within the distribution system reflects a temperature signal from Pemberton Creek recharge, and not due to another reason such as heating of water in the reservoir, this indicates a relatively short time of travel (less than 30 days) between Pemberton Creek and the pumping wells.

Water quality data analyzed for the Villages' three source wells support the interpretation that recharge comes primarily from Pemberton Creek and infiltration from surface. The water samples taken from the wells are characterized as calcium-bicarbonate type waters with very low total dissolved solids (26 to 84 mg/L), typical of very young and recently recharged groundwater. Bedrock groundwaters are typically more highly mineralized, particularly if the residence time in the bedrock is longer.

It is concluded that leakage from the bed of Pemberton Creek is the most significant source of recharge for the Pemberton Creek Fan Aquifer, although snowmelt and direct precipitation on the surface of the fan also contribute to a lesser extent. Groundwater discharging into the fan from underlying bedrock is expected to have only a very minor contribution to recharge.

Based on water and air temperature data, the time for groundwater to travel to the pumping wells from Pemberton Creek may be less than 30 days, although this assessment is preliminary. Measurement of water temperature at the source wells and in Pemberton Creek would assist in resolving this interpretation.

4.4 Aquifer Parameters

Aquifer parameters are determined from pumping tests and are used in assessing well capture zones and groundwater velocity. The original pumping tests conducted on Well #1 and Well #2 were analyzed by Golder (2004) to estimate aquifer transmissivity (T). The transmissivities, saturated aquifer thicknesses (b) and hydraulic conductivities (K) are summarized in Table 3 as follows:

Table 3 – Estimated Aquifer Parameters

Well	Transmissivity (m^2/s)	Saturated Thickness (m)	Hydraulic Conductivity (m/s)
Well #1	$7x10^{-3}$	35	$2x10^{-4}$
Well #2	$1x10^{-3}$	35	$3x10^{-5}$

To estimate groundwater velocity it is also necessary to determine representative values for effective porosity in the aquifer and the hydraulic gradient, or the slope of the water table across the fan aquifer. A value of 0.25 (dimensionless) is considered representative for Pemberton Creek Fan Aquifer sediments. Determining the hydraulic gradient requires measurements of the elevation of the water table at three or more points in the aquifer under conditions that are not influenced locally by pumping. Surveyed water levels under non-pumping conditions are not available and a hydraulic gradient of 0.02 m/m has been assumed based on conditions measured in the fan aquifer of Britannia Creek.

4.5 Aquifer Vulnerability

The aquifer classification previously conducted by the MOE based on aquifer mapping in the Pemberton Valley identified the aquifer (0326) as highly vulnerable to contamination, with a low level of demand and utilization. A previous source water assessment of the Villages' source wells conducted by MOE and Coast Garibaldi Health used the well logs to calculate an Aquifer Vulnerability Index (AVI) (J. Maxwell, undated). The AVI was developed by the Prairie Provinces Board and considers the hydraulic resistance of the geologic materials overlying the aquifer in question (Van Stepvoort et. al., 1992). Using the AVI method, it was concluded the Villages' source wells were Highly to Extremely Highly vulnerable to contamination from surface sources of contamination. Based on our review of logs for the test holes and production wells, and calculations using the AVI method, we agree with the vulnerability classifications determined by MOE and Maxwell. However, given the relatively small (approximately 4 ha) area of the fan that is highly productive and the existing level of aquifer development, we also conclude that the level of utilization is moderate to heavy.

The Pemberton Creek Fan Aquifer is considered highly vulnerable to contamination from surface sources and is moderately to heavily utilized for water supply.

5.0 WELLFIELD OPERATION AND WATER QUALITY

Currently, the Village operates the wellfield by alternating operation of Well #2 and Well #3. Well #1 is only operated on an emergency basis, for example, when extra flow is required for firefighting. The water supply is equipped with a SCADA system that is set up to monitor water levels in Wells #2 and #3, the pumping rate and chlorine residual. Following chlorination, water is pumped from the water supply wells to a steel tank reservoir located above the Village, with the water then flowing by gravity to end users via a closed loop water distribution system. Wells #1 and #3 are located in Pioneer Park south of Aster Street and Well #2 is located in Fougberg Park north of Aster Street.

Results of monitoring of the combined flow rate from Wells #2 and Well #3 and water levels measured in the wells using the SCADA system are plotted in Appendix A. The combined pumping rate is lower through the October to May period ranging from approximately 16 to 19 L/s. Demand increases from May through the summer peaking at an average daily rate of 38 L/s through August. Average water levels in the pumping wells decline by about 4 m in response to heavier summer pumping, but appear to recover to pre-summer pumping levels during the winter.

Water samples are collected weekly from the source wells for bacteriological analysis and annually since 2009 for analysis of physical and chemical parameters. In addition, monitoring and sampling is conducted weekly at a number of locations throughout the distribution system for bacteriological analysis, residual chlorine, temperature and pH.

5.1 Groundwater Supply Wells

Copies of the original well logs for Well #1 and Well #2 presented in the Pacific Hydrology (1992, 1997) reports are provided in Appendix B. We could not locate a log for Well #3 and a description of the construction is summarized from Earth Tech (2009).

5.1.1 Water Supply Well #1

Well #1 (Well Tag Number 74929/ Well ID Plate Number 815) was constructed in 1992 at an eight inch (200 mm) diameter to a depth of 25.6m, and completed with a telescopic well screen over the depth interval of 21 m to 25.6 m below ground in water-bearing sand and gravels. The original well static water level was 9.43 m below the top of steel casing (0.75 m above ground surface). The well lithology consists of sand and gravel deposits extending from ground surface to the base of the well. However, the sand and gravel deposits were noted to be silty over the depth range of 4 m to 11.6 m, and partially cemented between depths of 11.6 m to 18 m. The well was constructed with a 10 inch cemented surface casing extending to a depth of 5m below grade around the well casing, and is situated within a locked pumphouse building, with a concrete floor.

The 200 mm diameter well casing extends approximately 400 mm above the pumphouse floor, and is sealed with a watertight well cap, with a pump power cable and riser pipe extending through the well seal. The well is fitted with a submersible pump and had an initial rated yield of 29.1 L/s. Well yield reported declined over time and the well was rehabilitated in 1997. The original specific capacity of Well #1 in 1992 was 5.71 L/s/m which declined to 3.77 L/s/m following the 1997 rehabilitation. The yield declined by 2004 to approximately 10.7 L/s, at which point it was removed from active service, and is now only used as an emergency backup well.

5.1.2 Water Supply Well #2

Water Supply Well #2 (Well Tag Number 74927 / Well ID Plate Number 816) was constructed in 1997 at a 300 mm diameter to a depth of 41.8 m, and completed with a telescopic screen over the depth interval of 35.6 m to 41.7m below grade in water-bearing sand and gravel deposits. The well lithology consists of silty gravel deposits from ground surface to a depth of 5 m, and sand and gravel deposits from a depth of 5 m to 41.7 m, overlying bedrock.

The well is located within a subsurface concrete vault, completed with a locked steel hatch cover at grade, and the well vault located within a fenced wooden enclosure. The floor of the vault is approximately 2.5 m below grade. The well casing extends approximately 500 mm above the concrete base of the vault, and is sealed with a watertight well cap, with a pump power cable and riser pipe extending through the well seal. The well is fitted with a submersible pump, and has a rated maximum yield of 62.5 L/s. Well #2 was originally tested at 76.0 L/s in 1997. The specific capacity determined at that time was 6.36 L/s/m and the static water level was 7.20 m below the top of steel casing (0.81 m above ground surface).

5.1.3 Water Supply Well #3

Well #3 was constructed in 2008 at a 200mm diameter, and completed with a telescopic screen over a depth interval of 41.5m to 46m in water-bearing angular sand and gravel/broken rock at the base of the Pemberton Creek Fan Aquifer (Earth Tech, 2009). The well lithology consists of sand and gravel deposits extending from ground surface to a depth of 28m, underlain by silt deposits from a depth of 28m to 32m, and angular gravel and/or broken rock from a depth of 32m to 46m, at which point bedrock was encountered.

The well is accessed via a locked metal above-ground vault, with an adjacent below-grade valve chamber, sealed with a locked metal cover at grade. The well casing extends 330 mm above the concrete base of the vault, and is sealed with a watertight well cap. The well is fitted with a submersible pump, and has a Pitless Adaptor connection to the Village water distribution system, with a rated maximum yield of approximately 50 L/s. We were unable to locate the construction log for this well and information on the surface sealing as required under the Ground Water Protection Regulation (GWPR) is unavailable. We did contact Field Drilling Contractors who carried out drilling of test holes in 2007, but they had no records for the production well. It is assumed that Well #3 is constructed with a sealed surface casing extending to 4.6 m depth or greater as required under the GWPR, although this has not been verified by review of the construction log.

5.2 Groundwater Quality

Water sampling for bacteriological quality (Total Coliform and E. Coli) is undertaken weekly on all three source wells by Village staff. Records for the past three years were provided by VCH for our review.

Water sampling for chemical and physical parameters has been carried out annually in the two primary source wells (Well #2 and Well #3) since 2009 with sporadic testing in Well #1 and Well #2 before that time. Additionally, weekly measurements of temperature and pH are made at a number of locations within the distribution system.

5.2.1 Bacteriological Water Quality

Overall, the bacteriological quality of the Villages source water is very good. A summary of the sampling results is as follows:

Table 4 – Bacteriological Sampling Results

Well	Total No. of Samples	No. of Samples Containing Total Coliform	No. of Samples Containing E. Coli
Well #1	130	1	0
Well #2	134	0	0
Well #3	135	4	0

It is noted that all four detection of Total Coliform in Well #3 were measured in 2009, following commissioning of the well in 2008, with no detections during 2010 or 2011. The periodic detections in Well #3 during 2009 may be due to inadequate disinfection of the pump string and downhole equipment following installation, and not a reflection of bacteriological quality in the aquifer.

5.2.2 Chemical and Physical Water Quality

Results for all available chemical and physical tests are summarized and compared with the most recent Health Canada Guidelines for Canadian Drinking Water Quality (GCDWQ) in Table 5 (following text). Plots of water pH and temperature measured weekly at the Village Office are provided in Appendix A. Overall, the water quality is very good with all measured parameters meeting health-based GCDWQ maximum acceptable concentrations (MAC) with the exception of elevated turbidity in Well #1 measured during 2011 which may interfere with measures for water disinfection.

Based on major ion analysis, the waters from Well #1 and Well #3 are classified as a calcium-bicarbonate hydrochemical type with Well #2 classified as a calcium-bicarbonate-chloride water. The total dissolved solids content is very low ranging from 26 to 84 mg/L. These results are consistent with young, recently recharged groundwater which is expected given the proximity of Pemberton Creek acting as a recharge source and a relatively rapid rate of seepage through the aquifer. The chloride concentrations in Well #2 have increased from 5.7 mg/L in 1997, to 16 to 21 mg/L in 2009 to 2011. Although these concentrations are well below the CDWQG aesthetic objective of 250 mg/L for chloride, the results suggest some minor deterioration in water quality, likely from storage of ploughed snow during the winter in proximity to Well #2.

The water pH measured in the water system is mildly acidic with an average value of about 6.0 and ranging from 5.5 to 7.0. The CDWQG aesthetic objective for pH ranges from 6.5 to 8.5 and is based primarily on the potential for corrosion of water systems under low pH and mineral encrustation under higher pH. The mildly acidic conditions are believed to be associated with soils in the Pemberton area. Conditioning of the source waters to raise pH has been previously recommended, but not implemented, to control corrosion of copper plumbing.

Aside from pH, the only other parameters not meeting the CDWQG aesthetic objectives (AO) are total iron and manganese, and elevated turbidity (MAC), all of which were measured in Well #1 during 2011 (Table 5). It is noted that the hydraulic performance of Well #1 has deteriorated over time and it has been previously rehabilitated to control build up of iron on the well screen (Pacific Hydrology, 1997). As a consequence, it is now only used on an emergency basis. Turbidity measured in 2011 was 37.3 NTU relative to the MAC of 1 NTU. Total iron was 10.2 mg/L relative to the AO of 0.3 mg/L while total manganese was 0.282 mg/L relative to the AO of 0.05 mg/L. The elevated total iron and manganese concentrations observed in 2011 are believed to be associated with iron bacteria, as such wells often accumulate significant iron and manganese-impregnated bacterial growths over time, which get partially released under pumping conditions. Decreases in the well yield of Well #1 were previously attributed to growth of iron bacteria by Pacific Hydrology in correspondence to Associated Engineering (May 28, 2003).

6.0 WELL CAPTURE ZONE ANALYSIS

The capture zone of a water supply well is defined as the aquifer zone around the well (both laterally and vertically) that contributes water to the well during pumping. The well capture zone delineates the area of an aquifer that has the potential to contaminate a given water supply well, through recharge of potential contaminants from ground surface located within this zone and the physical boundaries must be defined for the well protection planning process. There are a number of ways to determine the capture zones including a fixed radius approach, analytical equations and numerical computer modeling. Based on the hydrogeologic setting of the Villages' wells and the Pemberton Creek Fan Aquifer, analytical equations are considered appropriate and have been used in this assessment.

6.1 Previous Work

Previous calculations of the capture zones for the Villages' wellfield are described in Maxwell (undated) and Pacific Hydrology Consultants (1997).

Maxwell used a "calculated fixed radius" approach which is considered as overly conservative and not realistic for the given hydrogeologic setting. This analysis indicated the capture zones about the Villages' wells had radii of 360, 800 and 1,130 m based on 1, 5 and 10 year times of travel. These capture zones extend well into the finer grained valley bottom sediments east of the Pemberton Creek Fan Aquifer and are not considered realistic.

Pacific Hydrology used analytical equations to determine the capture zone; however, they used an assumed pumping rate of 76.0 L/s that is double the current maximum pumping rate of 38.0 L/s of the wellfield (Appendix A). Assuming a groundwater flow direction approximately west to east across the alluvial fan, this analysis indicated a capture zone 1,140 m wide (north to south centred on the wells) extending 370 m upgradient (west) and 370 m downgradient. Based on the Villages' actual pumping rates, this analysis is also considered overly conservative.

6.2 Capture Zone Using Analytical Equations for Groundwater Flow

The well capture zone was based on the combined pumping of Well #2 and Well #3, which operate in tandem. A composite well capture zone was determined for the two wells, given their proximity, reflecting the aggregate well capture footprint associated with pumping either of the two water supply wells. This results in a "composite" or combined area of drawdown within the Pemberton Creek Fan Aquifer, and thus a composite well capture zone. The well capture zone was based on the maximum daily pumping rate of roughly 38 L/s from either of the two water supply wells.

The analytical solution to estimate the well capture zone based on analytical equations outlined in the MOE's Well Protection Toolkit, is presented below:

$Y = Q / 2000 (T) (i)$ and $X = Y/(3.14)$

where : Y = half width of the well capture zone (m)
i = hydraulic gradient
X = distance to the capture zone boundary downstream of the well (m)
T = transmissivity of the aquifer (m^2/s)

Q = pumping rate (L/s)

Using the maximum pumping rate of 38 L/s, the maximum aquifer transmissivity of $7x10^{-3}$ m^2/s (Table 3), and a hydraulic gradient of 0.02 m/m, the width of the capture zone is 270 m (Y=135 m) and the distance X downgradient to the stagnation point is 45 m. Based on these values, recognizing that both wells are pumped alternatively, and recognizing that there is some uncertainty in the actual direction of the groundwater gradient across the fan, the combined well capture zone is outlined in green on Figure 3. The capture zone extends upgradient to Pemberton Creek, interpreted as the primary aquifer recharge source and the southwestern boundary of the aquifer.

6.3 Time of Travel

The groundwater time of travel in the capture indicates the boundaries where contaminants could potentially reach the pumping wells at differing time periods. Travel time boundaries are typically determined for 1, 5 and 10 year times of travel for use in well protection planning. Land use activities with potential to cause aquifer contamination are considered as "higher risk" within the 1 year time of travel boundary in comparison to those located within a ten year time of travel. Groundwater velocity (v), can be estimated from the hydraulic conductivity (K), hydraulic gradient (i) and effective porosity (n) by the following relation:

$$v = (Ki)/n$$

Assuming the maximum and minimum values for hydraulic conductivity shown in Table 3, and the effective porosity and hydraulic gradient described in Section 4.4, groundwater velocity is estimated to range from approximately 0.2 to 1.5 m/day. This describes the velocity of seepage through the aquifer as it is unaffected by the pumping wells. In proximity to the pumping wells, hydraulic gradients are steeper due to pumping drawdowns and groundwater velocity is greater. The distance from Pemberton Creek to the pumping wells ranges from 200 to 250 m. Pemberton Creek represents the farthest point in the capture zone from the wells and is also interpreted as the primary aquifer recharge source. Based on the distances between the wells and Pemberton Creek, the time of travel ranges from a minimum of 130 days to a maximum of 1,250 days. Accounting for increased seepage velocity near the pumping wells, the time of travel may be as short as 100 days. **To be conservative, the time of travel throughout the entire capture zone should be considered less than one year and may be as short as 100 days.**

Note that the method of determining groundwater travel time based on calculation of groundwater velocity from aquifer parameters is not in agreement with the interpretation of a much shorter travel time based on water temperatures measured in the water system as described in Section 4.3. This could mean that water temperature measured in the water system is affected by factors other than groundwater temperature such as heating and cooling in the reservoir, or it may be due to more rapid groundwater flow through higher permeability layers in the fan aquifer.

7.0 CONTAMINATION SOURCE ANALYSIS

A groundwater protection zone has been defined that includes the well capture zone and highly productive area of the aquifer, both of which are shown on Figure 3. The groundwater protection zone, as well as activities that could potentially cause contamination of the water source are shown on Figure 5. Note that the groundwater protection zone also includes any land and water use in the Pemberton Creek watershed that could diminish the creek flows or degrade the water quality. **The next time the Village amends the Official Community Plan, consideration should be given to designating the groundwater protection zone as an Environmentally Sensitive Area.**

Land use on the fan area within the groundwater protection zone includes a mixture of residential, park and commercial use. Residential and commercial developments in the downtown area are serviced by a sanitary sewer system and nitrates and pathogens from on-site septic systems are not considered as potential contaminant sources. The primary potential sources of contamination are point sources associated with commercial activities and the BC Rail line, which is considered as a linear source. Pemberton Creek may also be considered a linear source.

7.1 Point Sources

A previous search of MOE's Site Registry and review of BC Rail environmental records, and review of historical aerial photographs indicated no evidence of registered contaminated sites or records of spills in the vicinity of the Villages' wells (Golder, 2007). Based on review of available information and site reconnaissance undertaken during preparation of this GPP, five point sources of potential contamination were identified within and in close proximity to the groundwater protection zone (Activities 1 through 5, Figure 5).

<u>Garibaldi Tire Services – Location 1, Figure 5</u>

Garibaldi Tire Services Ltd. (Black's Hot Wheels) is located at 1380 Aster Street less than 10 m west of Well #3 and approximately 50 m west of Well #1. Inspection through the windows of the service bays indicated use and storage of parts washing solvent (e.g. Varsol), a low molecular weight petroleum mixture containing volatile organic compounds. An enclosed storage area is located at the east end of the building. The storage area, service bays and entrance area have asphalt and concrete surfaces that would limit the likelihood of any spills infiltrating to ground, although the ground surface in Pioneer Park where Wells #1 and #3 are situated is grass-covered. Given the very close proximity of the wells, any significant spills (e.g. a 210 L drum of Varsol overturning and spilling) could have very serious consequences for the Villages' water system. It was also indicated by Maxwell (undated) based on interviews that a service station was formerly located at the site of the tire shop and that it was "decommissioned due to leaking fuel storage tanks".

There is also the remote potential for aquifer contamination from a fire at the tire store due to organic contaminants released from burning tires, should this occur. Assuming the fire is extinguished with water, there is the potential for contaminants to infiltrate to ground in the area surrounding the wells. While such a scenario is only a remote possibility, it would constitute a significant contaminant risk to the aquifer. **The Village should develop a fire fighting plan that could consider alternatives such as use of foam in the event of a fire at the tire shop and should also consider involving the management of this business in the implementation of the GPP, for example, through awareness and best practices for use and storage of hazardous substances. Over the long-term, the Village should consider planning tools so that this property immediately adjacent to the wells is used for lower risk activities.**

<u>Storage of Ploughed Snow in Fougberg Park – Location 2, Figure 5</u>

Well #2 is located in Fougberg Park and the areas outside the wellhead are utilized for snow storage during the winter. Discussions with Village staff indicate that salt use for deicing of roadways is minimized and sanding is used. As discussed in Section 5.2.2, there is some evidence of slightly elevated chloride concentrations in water samples from Well #2 which likely associated with storage of ploughed snow at this location. **Although the concentrations are presently well below the GCDWQ aesthetic objectives, in the interest of maintaining the very good aquifer water quality, alternate locations should be considered for storage of ploughed snow**.

<u>Rona Hardware – Location 3, Figure 5</u>

The Rona Hardware store is located directly north of Well #2. These businesses store products such as paints, solvents, antifreeze and treated lumber. The storage areas exterior to the building are paved and the overall risk of a significant spill infiltrating into the ground is considered very remote. **The Village should engage the store management so that they are aware that their business is located within the well capture zone and to implement best practices for storage and disposal of potentially hazardous products.**

<u>Pemberton Esso – Location 4, Figure 5</u>

The Pemberton Esso service station is located at the intersection of Birch Street and Prospect Street and is located on the edge of the interpreted well capture zone of Well #2. Inspection of the site indicates the underground storage tanks appear to be located in an underground structure with secondary containment and monitoring facilities for leak detection. There was no evidence of groundwater monitoring wells located outside the storage tank area to suggest previous investigations relating to petroleum leaks from storage tank or underground piping systems. **The Village should engage the management of this business so that they are aware that the service station is located in or near the well capture zone and to promptly notify the Village in the event of a spill or detected leakage of petroleum products.**

<u>BC Hydro Yard – Location 5, Figure 5</u>

BC Hydro has a yard and storage building located on Aster Street, west of the Villages' wells and within the interpreted capture zone. We were unsuccessful in attempting to contact BC Hydro. According to Village staff (R. Mack, per. comm.), the yard area was formerly used for storage of electrical transformers and the entire yard area was apparently excavated to remove any stained soils approximately 10 years ago and replaced with gravel.

Electrical transformers contain dielectric oils and polychlorinated biphenyls (PCBs) were historically used, although their use has been phased out since the late 1970s. PCBs are persistent (do not degrade and remain in the environment), are highly insoluble in water and very immobile in the subsurface, tending to absorb to soils rather than dissolving and infiltrating with snowmelt or precipitation. **The Village should engage management or senior staff at the BC Hydro yard so that they are aware that the yard is located within the well capture zone and to maintain best practices for storage of any hazardous products and proper handling and disposal of any hazardous wastes generated.**

7.2 Linear Sources

The BC Rail corridor is considered as a potential linear source of contamination. Pemberton Creek and its watershed must also be considered in groundwater protection planning.

<u>Pemberton Creek Watershed</u>

As discussed in Section 3.2, one alternative considered for power generation on Pemberton Creek involved diversion of a large portion of the flow via a penstock to a powerhouse located near the base of the alluvial fan. As noted, this could seriously impact aquifer recharge and diminish the quantity of groundwater available for pumping.

The watershed is currently used for forestry and logging and road construction activities may result in increased sediment load. Periodic increased sediment loads to Pemberton Creek are not expected to influence aquifer groundwater quality. There were formerly two small mineral claims in the watershed where elevated copper, molybdenum, lead, zinc and gold values were identified in soils, although these claims have now lapsed.

<u>BC Railway – Location 6, Figure 5</u>

The BC Rail mainline runs through Pemberton and is located along the eastern margin of the capture zone. Historically, there was also a siding located in the central part of the Village where rail cars were temporarily stored. There are a number of potential types of contaminants that may be associated with railyard activity including herbicides sprayed for vegetation control, various types of hydrocarbons (e.g. diesel, heavy oils) and well as a variety of products transported by railcar. For example, a CN Rail derailment in 2007 resulted in a large spill of caustic soda (sodium hydroxide) used by pulp mills into the Chekamus River south of Pemberton. According to information reviewed by Golder (2007), there are no records of spills in Pemberton based on BC Rail's files.

Although a number of these potential contaminants are organic chemicals (hydrocarbons, herbicides), contamination of the mainline or former siding would also be expected to result changes to major ions and total dissolved solids in the groundwater. The water quality monitoring conducted by the Village to date indicates the groundwater has very low total dissolved solids and a major ion chemistry indicative of young, recently recharged groundwater with no evidence of contamination from industrial sources. **However, given the proximity of the tire shop, the use of solvents at that location and the reported former service station, we consider it prudent to analyze the Villages' water for mobile and common organic contaminants such as benzene, ethylbenzene, toluene and xylenes (BETX).**

8.0 GWUDI Status Assessment

Given the direct connection between Pemberton Creek and the Pemberton Creek Fan Aquifer, and the fact the aquifer is unconfined with a relatively shallow water table, groundwater in portions or all of the aquifer may potentially be "groundwater under the direct influence of surface water" (GWUDI). Groundwater under the direct influence of surface water is considered more susceptible to contamination from pathogens present in surface waters such as Giardia and *Crytosporidium,* which may require additional methods for disinfection beyond chlorination.

British Columbia has been developing guidance for determining "groundwater at risk of containing pathogens" (GARP) and "groundwater under direct influence of surface water" (GWUDI) and has published these in draft form (Revision 8 dated February 24, 2012). This guidance references applicable provincial legislation governing groundwater protection and procedures developed for other jurisdictions, and involves four stages:

Stage 1: Screening Tool
Stage 2: Preliminary Hydrogeological Investigation
Stage 3: Advanced Hydrogeological Investigation
Stage 4: Long-Term Water Quality Monitoring

This assessment covers Stages 1 and 2, and recommendations for long-term monitoring (Stage 4) are covered in the report recommendations.

Stage 1 involves a risk/vulnerability assessment based on factors such as site location, aquifer type and setting, well construction and available water quality information. Screening checklists were completed for Stage 1 and are presented in Appendix 3. Stage 2 involves more detailed work such as assessing groundwater flow pathways and travel times between potential pathogen sources such as surface water and pumping wells.

Potential risk factors for GARP identified during this assessment included elevated turbidity in Well #1, detections of total coliform bacteria in Well #3 during 2009, the relatively shallow water table and unconfined nature of the aquifer, locations of the wells within a floodplain, and storage of ploughed snow near the wellhead of Well #2. There is also an uncertainty in the time of groundwater travel from Pemberton Creek to the wells with hydrogeologic calculations based on groundwater velocity suggesting a travel time of 100 days or greater (a low risk) and temperature data measured in the water system suggesting a much smaller time in the order of two weeks (a higher risk).

With respect to turbidity, it is noted that Well #1 is only used on an emergency basis and there is no recent history of total coliform detections. With respect to total coliform detections in Well #2, it is noted that these occurred in 2009 following commissioning of the well, and no detections have been measured in 2010 or 2011. With respect to the location of the wells within a floodplain, it is noted that the Village is protected by dykes. It is assumed that in the event of an extreme flood overtopping the dykes, an Emergency Response Plan would cover procedures such as increased disinfection and monitoring frequency of the water system. The construction of all wells appears to meet the requirements of the GWPR with respect to surface sealing, well caps and covers, floodproofing and wellhead protection, although the construction log was not available for Well #3 and therefore, the presence of an adequate surface seal cannot be verified.

The wells are located over 200 m from Pemberton Creek, the well screens are located greater than 15 m below ground surface, and the time of travel for seepage moving from surface sources in the creek to the wells is interpreted to be well in excess of 50 days based on hydrogeologic calculations, which would represent low risk for GWUDI.

Overall, we conclude that the Villages water system is at low risk for GARP and GWUDI, subject to confirming that Well #3 has an adequate surface seal, that the Village commits to not using the wellhead areas for storage of ploughed snow, and resolving the discrepancy of travel time estimates to the wells from Pemberton Creek based on hydrogeologic calculations and temperature measurements made in the water system.

9. CONCLUSIONS

The following conclusions are made with regard to the Village of Pemberton water supply wells, Pemberton Creek Fan Aquifer and current source protection measures:

1. The Village water supply wells (Wells #1, #2 and #3) are screened in a semi-confined to unconfined sand and gravel aquifer (Pemberton Creek Fan Aquifer), between depths of 21 m to 46 m. The highly productive portion of the aquifer is limited to approximately 4 ha in area in the central portion of the fan. The aquifer is classified as being highly vulnerable to sources of surface contamination and is moderately to highly utilized for water supply;

2. The construction of the wells appears to meet all requirements of the Ground Water Protection Regulation with respect to surface sealing, well caps and covers, floodproofing and wellhead protection. We could not confirm the adequacy of the surface seal for Well #3 (drilled in 2008) because no construction log is available.

3. Wells #2 and #3 are the primary source wells with Well #1 used only as an emergency back up well. The performance of Well #1 has historically declined in spite of efforts to rehabilitate the well due to growth of iron bacteria. Current water demand ranges from about 22 L/s during the winter to a peak summer demand of 38 L/s.

4. The primary source of aquifer recharge is interpreted to be leakage from the bed of Pemberton Creek that flows across the southwest margin of the alluvial fan. Infiltration of snowmelt and precipitation, and discharge of groundwater from bedrock into the fan deposits are a secondary and much less significant source of recharge.

5. A small hydro feasibility study carried out for the Village examined alternatives for power generation on Pemberton Creek with one alternative intercepting a very significant portion of the creek flow in a penstock and diverting this to a powerhouse lower in elevation than the alluvial fan. It is concluded that this could seriously impact aquifer recharge and diminish the water available for pumping.

6. The water quality of the Pemberton Creek Fan Aquifer is a calcium-bicarbonate type with very low total dissolved solids typical for young, recently recharged groundwater. The groundwater is mildly acidic and somewhat corrosive for copper plumbing. Aside from its mildly acidic character, water quality from the two primary source wells is very good and meets Guidelines for Canadian Drinking Water Quality for all of the chemical and physical parameters analyzed. Well #1, utilized only on an emergency basis to meet fire flows, has elevated turbidity, iron and manganese due to iron bacteria growths that have been historically problematic. There is some evidence of slightly increased chloride concentrations in Well #2 that are probably due to storage of ploughed snow near the wellhead in Fougberg Park, although the concentrations are well below the drinking water quality guidelines.

7. The bacteriological water quality has been very good with the exception of some detections of total coliform in Well #3 during 2009, following commissioning of the well in 2008. Lack of any detections in 2010 and 2011 suggest the total coliform detections may have been the result of well commissioning, such as inadequate disinfection of the pump string or other downhole equipment.

8. Potential sources of contamination within and near the well capture zone and groundwater protection area include a tire shop, storage of ploughed snow near one of the wellheads, a commercial hardware store, a service station, a BC Hydro property where electrical transformers were formerly stored in a gravel yard, and the BC Rail mainline and an historical siding where rail cars were temporarily stored. The most significant concern is the tire shop, located immediately adjacent to the wellhead of Well #3, where parts washer solvents and other hazardous materials are stored.

9. An assessment of the risk of the water supply wells to pathogens such as Giardia and *Crytosporidium* originating from surface water or ground surface indicates the risk should be low, although this is subject to confirming an adequate surface seal for Well #3, a commitment by the Village not to store ploughed snow near the wellheads, and resolving a discrepancy in the interpreted travel time of

seepage from Pemberton Creek to the wells based on hydrogeologic calculations of groundwater velocity and temperature measurements made in the water system.

10. RECOMMENDATIONS

The following recommendations are made with regard to groundwater source water protection measures for the Village of Pemberton water supply system and the Pemberton Creek Fan Aquifer:

1. Designate the groundwater protection zone as an environmentally sensitive area in the Villages' Official Community Plan;

2. Do not commit to any small scale hydro generation project that would divert significant portions of the flows in Pemberton Creek from the fan area where the aquifer is recharged;

3. Form a groundwater source protection planning committee that includes representation from businesses located in the well capture zone. Communicate key findings of this groundwater protection plan with management of businesses identified as having a potential to cause contamination of the aquifer.

4. Commit to developing alternate locations for winter storage of ploughed snow away from wellheads;

5. Locate a copy of the construction log for Well #3 and confirm that the well has an adequate surface well seal in accordance with the Ground Water Protection Regulation;

6. Measure and record temperature weekly from both primary source wells and Pemberton Creek for a period of one year. Have a qualified person review this to determine if there is a temperature signal propagated through the aquifer to the wells from the creek and assess the time of travel. Following this, review the GARP and GWUDI risk classification;

7. During 2012 and every three years thereafter, test the source wells for volatile organic compounds (VOCs) to assess the potential for contamination from hydrocarbon sources such as petroleum fuels and parts washer solvents;

8. Have a qualified person plot and analyze historical water levels in both primary source wells every three years to determine if water levels remain stable year over year or are declining. Declining water levels can indicate decreasing well performance or an overdraft (overpumping) of the aquifer.

11. CLOSURE

Thank you for the opportunity to prepare this groundwater protection plan for the Village of Pemberton. This report has been prepared for the Village who may share it with agencies and individual involved with groundwater protection and drinking water supply. Any others using this report do so at their sole risk.

Respectfully submitted,

Enterprise Geoscience Services Ltd.

John Balfour, M.Sc., P.Eng.
Hydrogeologist

Owen Quinn, M.Sc., P.Geo.
Hydrogeologist

REFERENCES

Associated Engineering Ltd., 2003. The Village of Pemberton – Water Conditioning and Chlorination.

BC Ministry of Environment, 2003. Drinking Water Protection Regulation

Coast Garibaldi Health, 2000. Drinking Water Source Assessment Summary Report, Village of Pemberton Water System, Pemberton, BC

Coast Garibaldi Health, 2003. Village of Pemberton Water Works - Letter to Village of Pemberton Council.

Earth Tech / Aecom, 2009. As-Built Drawings for Village of Pemberton Water Supply System

Geologic Survey of Canada Paper 73-17, 1973. Pemberton (East Half) Map Area British Columbia 92J by J.A. Roddick and W.W. Hutchison.

Golder Associates, 2004. Groundwater Exploration and Supply Development Village of Pemberton, BC.

Golder Associates, 2006a. Technical Memorandum #1, Groundwater Exploration (Phase 1) Pemberton Creek Alluvial Fan Aquifer, Village of Pemberton, BC

Golder Associates, 2006b. Technical Memorandum #2, Groundwater Exploration (Phase 1) Pemberton Creek Alluvial Fan Aquifer, Village of Pemberton, BC

Golder Associates, 2007a. Technical Memorandum #3, Groundwater Exploration (Phase 1) Pemberton Creek Alluvial Fan Aquifer, Village of Pemberton, BC

Golder Associates, 2007b. Technical Memorandum #4, Groundwater Exploration (Phase 1) Pemberton Creek Alluvial Fan Aquifer, Village of Pemberton, BC

Maxwell, J. (undated). Drinking Water Source Assessment Summary Report for Village of Pemberton, BC Ministry of Environment and Coast Garibaldi Health.

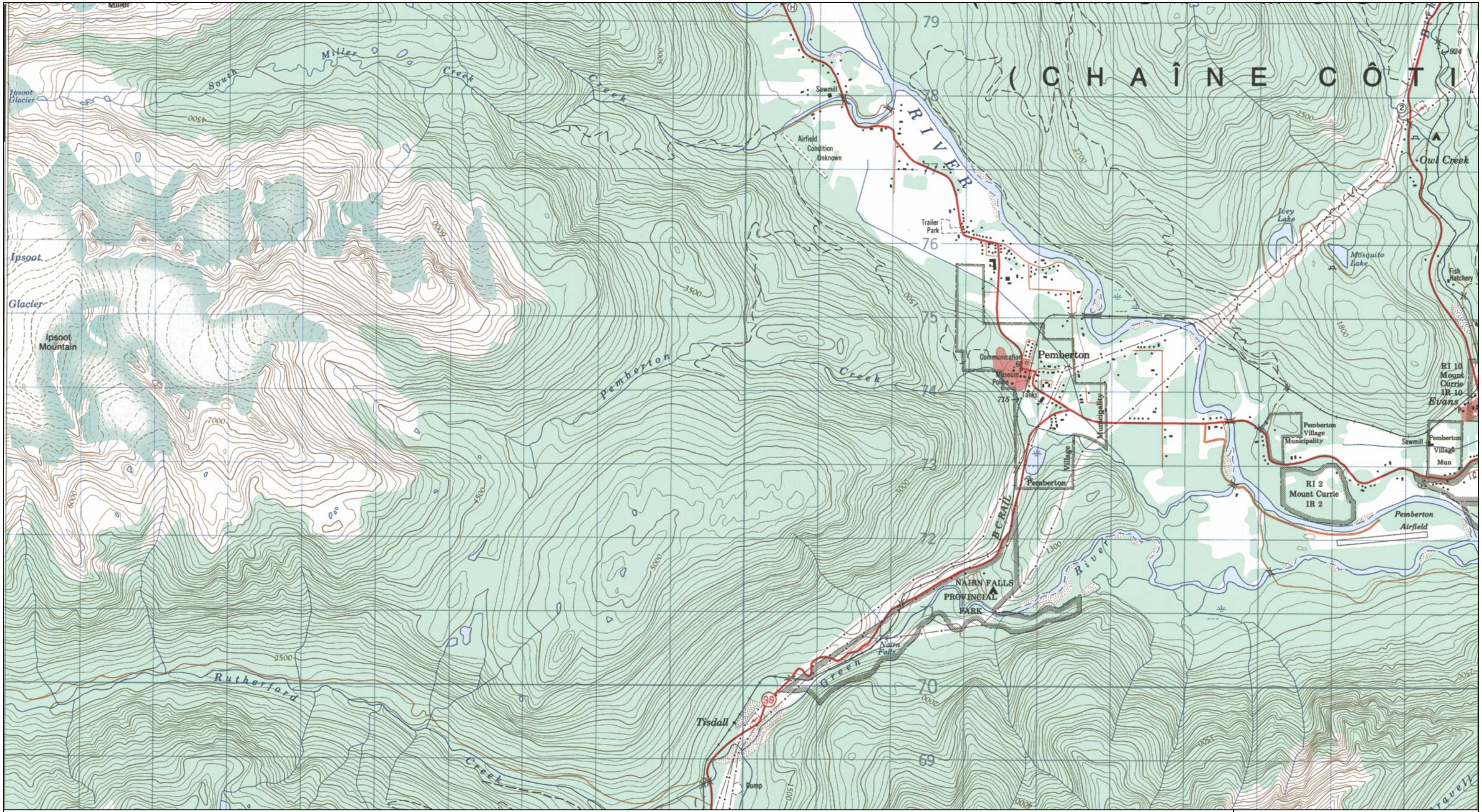
Precision Service and Pumps Inc., 2002. Well No.1 Maintenance.

Precision Service and Pumps Inc., 2002. Well No. 1 Performance History

Russell Mack, pers. comm..2012

Van Stempvoort, D., Ewert, L., and L. Wassenaar, 1992. AVI : A Method for Groundwater Protection Mapping in the Prairie Provinces of Canada. Prairie Provinces Water Board, Regina, Saskatchewan.

FIGURES

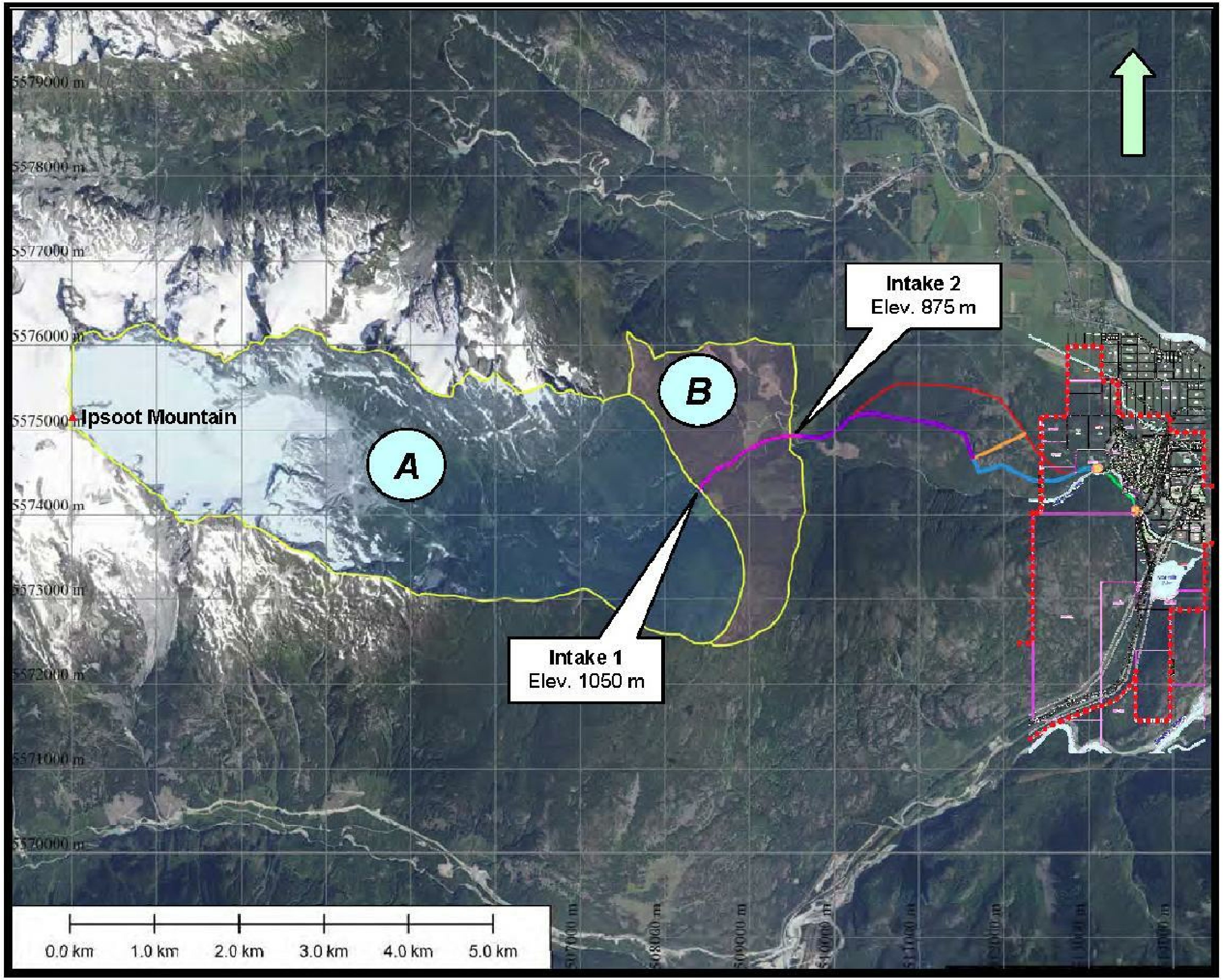


SCALE 1:50,000

0.5 0 0.5 1.0 2.0km

Enterprise Geoscience Services Ltd.
203 - 2902 West Broadway
Vancouver, BC, V6K 2G8

CLIENT: Village of Pemberton	
PROJECT: Groundwater Protection Plan	
TITLE: Location Plan	
DRAWN BY: YL	CHK. BY: JB
DATE: 2012/03/21	REVISED:
PROJ #: 01212	FIGURE 1



PEMBERTON CREEK SMALL HYDRO PROJECT

Pemberton Creek Basin

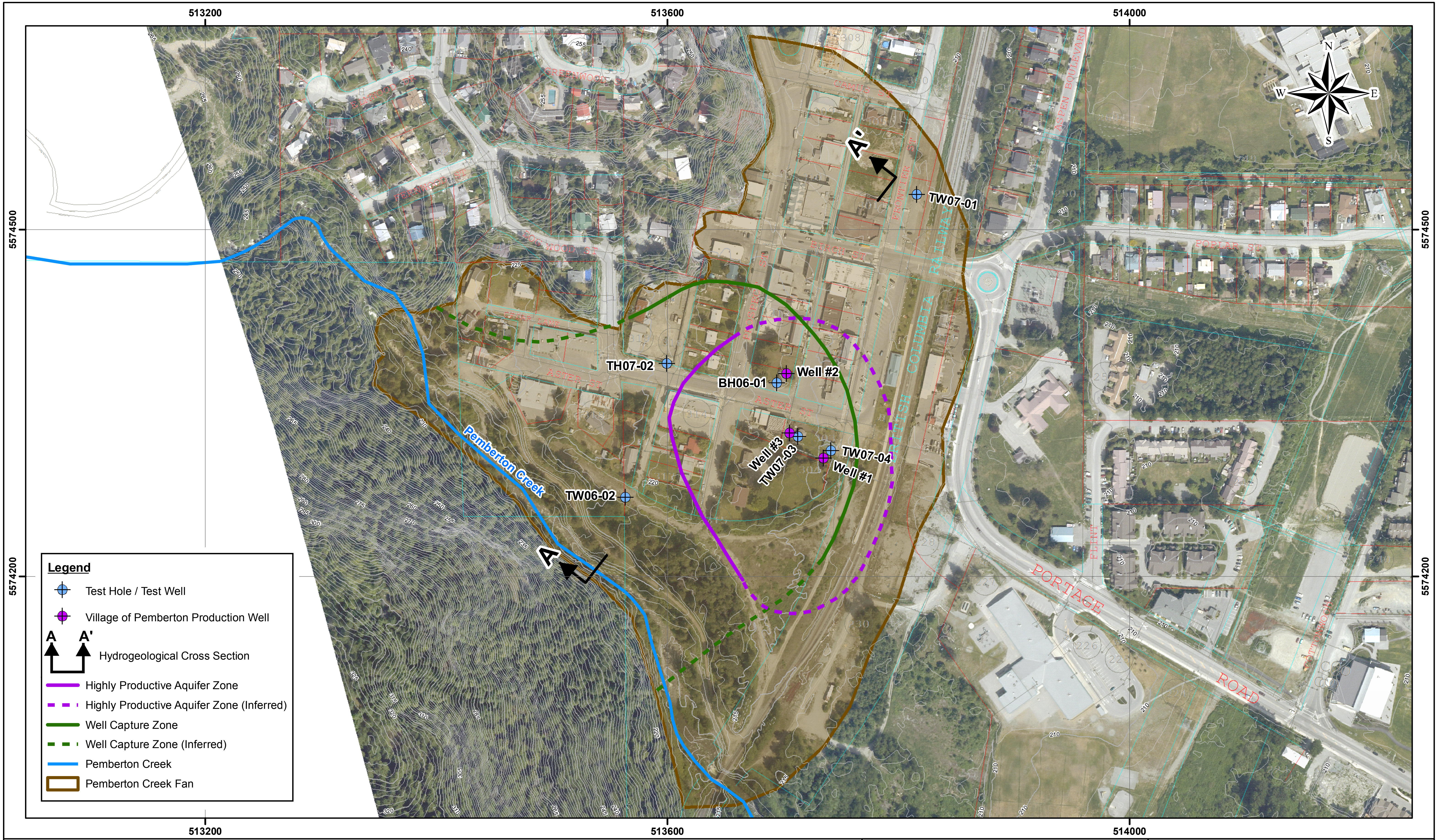
Area (A)	17.55 km^2
Area (B)	4.08 km^2
Combined:	21.63 km^2

Village of Pemberton Boundary (approx.)

Imagery courtesy of: Ryan River Hydro Joint Venture

Enterprise Geoscience Services Ltd.
203 - 2902 West Broadway
Vancouver, BC, V6K 2G8

CLIENT:	**Village of Pemberton**
PROJECT:	**Groundwater Protection Plan**
TITLE:	**Pemberton Creek Basin**
DRAWN BY: YL	CHK. BY: JB
DATE: 2012/03/21	REVISED:
PROJ #: 01212	FIGURE 2



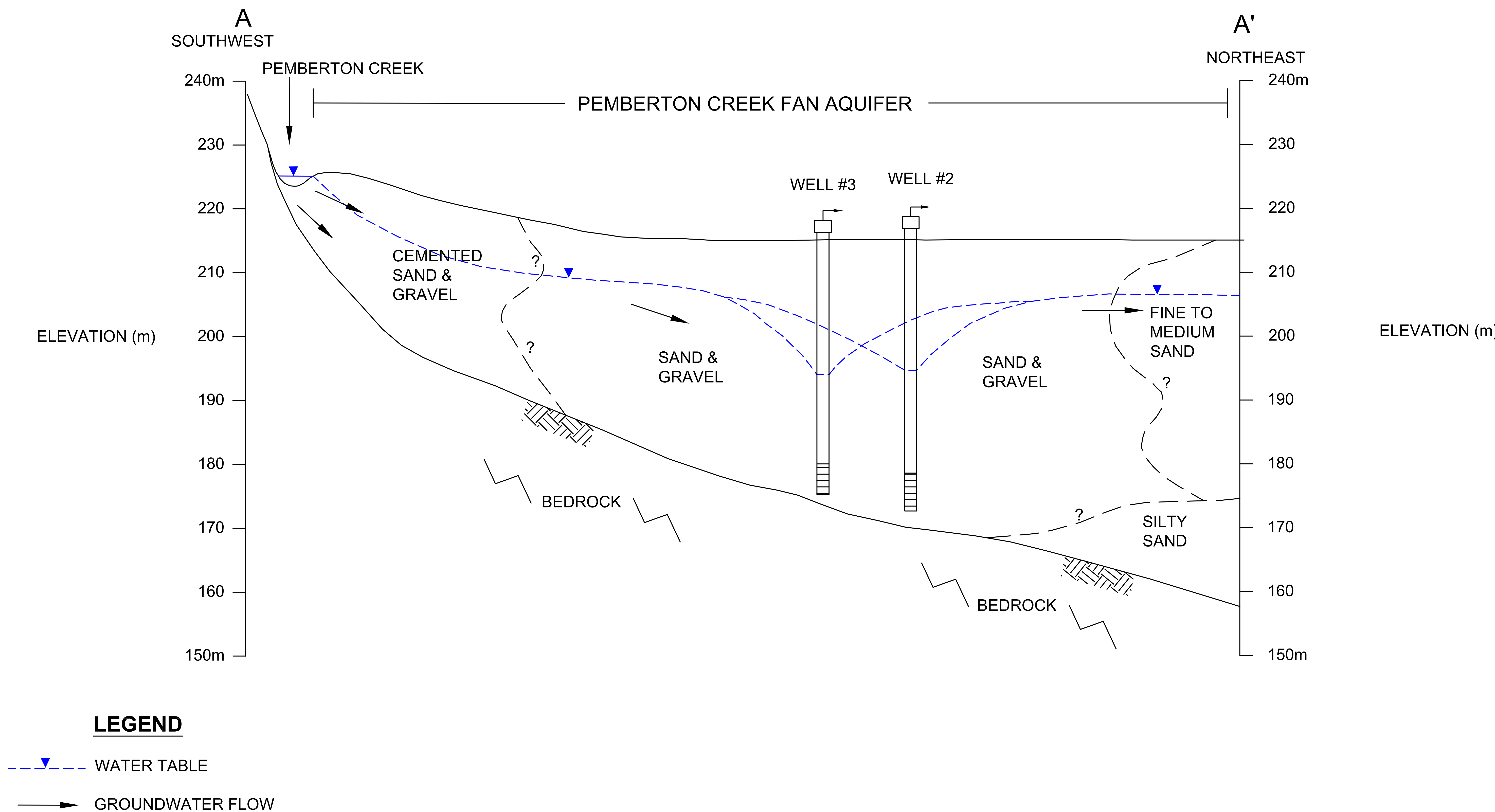
1:3,000

0 50 100 200 Metres

Note:
Time of groundwater travel in Well Capture Zone not shown. Groundwarer velocity in Pemberton Creek Fan estimated at 500m/yr. Time of travel from Pemberton Creek to production wells in the order of 150 days.

Enterprise Geoscience Services Ltd.
203-2902 West Broadway
Vancouver, BC, V6K 2G8

CLIENT: Village of Pemberton			
PROJECT: Groundwater Protection Plan		DRAWN BY: YL	CHK BY: JB
TITLE: Site Plan		DATE: 2012/03/28	REVISED: 2012/04/03
		PROJ #: 01212	FIGURE 3



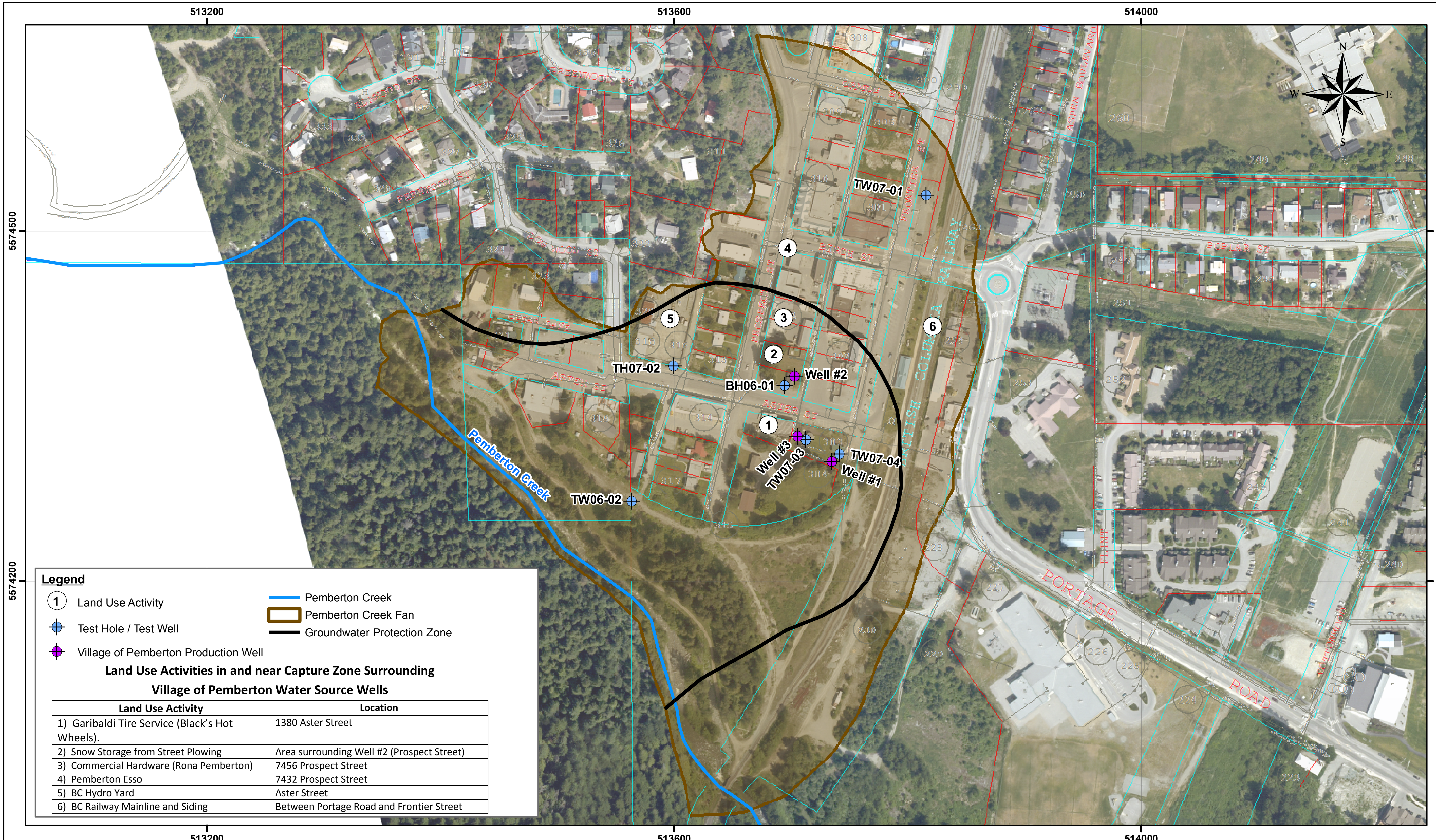
SCALE 1:1500

10 0 10 30 60m

2.5X VERTICAL EXAGGERATION

Enterprise Geoscience Services Ltd.
203 - 2902 West Broadway
Vancouver, BC, V6K 2G8

CLIENT:	**Village of Pemberton**		
PROJECT:	**Groundwater Protection Plan**		
TITLE:	**Schematic of Pemberton Creek Fan Aquifer Under Pumping Conditions**		
DRAWN BY:	YL	CHK. BY:	JB
DATE:	2012/03/29	REVISED:	2012/04/03
PROJ #:	01212		FIGURE 4



Legend

- ① Land Use Activity
- Test Hole / Test Well
- Village of Pemberton Production Well
- Pemberton Creek
- Pemberton Creek Fan
- Groundwater Protection Zone

Land Use Activities in and near Capture Zone Surrounding Village of Pemberton Water Source Wells

Land Use Activity	Location
1) Garibaldi Tire Service (Black's Hot Wheels).	1380 Aster Street
2) Snow Storage from Street Plowing	Area surrounding Well #2 (Prospect Street)
3) Commercial Hardware (Rona Pemberton)	7456 Prospect Street
4) Pemberton Esso	7432 Prospect Street
5) BC Hydro Yard	Aster Street
6) BC Railway Mainline and Siding	Between Portage Road and Frontier Street

1:3,000

0 50 100 200 Metres

Note:
The groundwater protection zone also includes the watershed of Pemberton Creek to avoid activities that can diminish flows or degrade water quality in Pemberton Creek, the primary recharge source of the Pemberton Creek Fan Aquifer.

Enterprise Geoscience Services Ltd.
203-2902 West Broadway
Vancouver, BC, V6K 2G8

CLIENT: Village of Pemberton			
PROJECT: Groundwater Protection Plan		DRAWN BY: YL	CHK BY: JB
TITLE: Groundwater Protection Zone		DATE: 2012/03/28	REVISED: 2012/04/04
		PROJ #: 01212	FIGURE 5

TABLES

Table 1

Mean Monthly Flow in Pemberton Creek and Mean Monthly Air Temperature In Pemberton

Month	Pemberton Creek Discharge (m^3/s)	Mean Air Temperature (^oC)
January	0.60	-5.0
February	0.44	-2.0
March	0.66	2.9
April	1.47	8.4
May	3.18	13.0
June	3.35	15.9
July	3.04	18.2
August	2.54	17.1
September	1.51	13.0
October	1.40	7.7
November	1.12	1.6
December	0.61	-3.0

Notes:

1) Discharge data based on records from Water Survey of Canada Station 08MG025 from 1987 to 2006.

2) Temperature data for Pemberton Meadows station (elev. 223 m).

TABLE 5 - Water Quality Data for Village of Pemberton Water System

Location	CDWQ MAC [1]	CDWQ AO	Well 1-92	Well #1	Well 2-97	Well 2-97	Well 2-97	Well #2	Well #2	Well #2	Well #3	Well #3	Well 3
Test Date			1992 [4]	7/26/2011 [9]	1997 [4]	2003 [5]	May-04 [6]	6/16/2009 [7]	6/21/2010 [8]	7/26/2011 [9]	6/16/2009 [7]	6/21/2010 [8]	7/26/2011 [9]
Physical Tests													
Colour (CU)		15	5	<5	<5	-	<5	<5	<5	<5	<5	<5	<5
Conductivity (µS/cm)			42	114	55	-	77	79	131	142	77	44	47
Total Dissolved Solids (mg/L)		500	34	52	32	-	37	62	76	84	58	24	26
Total Hardness as $CaCO_3$ (mg/L)			15.7	30.1	17.9	25	24	24.2	38.8	43.0	24.3	14.7	14.2
pH		6.5-8.5	6.5	6.72	6.23	-	6.20	7.5	7.4	6.76	7.4	7.2	6.68
Turbidity (NTU)	1 [2]		0.4	37.3	0.9	-	0.15	0.2	0.2	0.2	<0.1	0.5	<0.1
Dissolved Anions													
Alkalinity as $CaCO_3$			11.5	38	10	-	18.2	13	23	23	13	12	11
Alkalinity (PP as $CaCO_3$)			-	<0.5	-	-	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Bicarbonate (HCO_3)			14	46	12.2	-	22.2	16	28	28	15	15	14
Carbonate (CO_3)			-	<0.5	-	-	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Hydroxide (OH)			-	<0.5	-	-	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Chloride		250	<0.5	5.4	1.7	-	5.7	21	16	17	8.3	<0.5	0.6
Fluoride	1.5		<0.10	0.02	<0.02	-	<0.05	0.02	0.01	0.02	0.01	0.01	0.02
Sulphate		500	7.6	10	8.8	-	10.5	19	14	15	12	6.3	7.5
Nutrients													
Nitrate as N	10		<0.02	0.02	0.149	-	0.10	0.15	0.14	0.14	0.14	0.08	0.08
Nitrite as N	1		0.006	<0.005	<0.001	-	<0.002	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Nitrate plus Nitrite as N			-	0.02	-	-	-	0.15	0.14	0.14	0.14	0.08	0.08

Footnotes:

Concentrations are in milligrams per litre unless otherwise stated.

1. Summary of Guidelines for Canadian Drinking Water Quality, Health Canada, May 2008. MAC = Maximum Acceptable Concentration, AO = Aesthetic Objective.
The use of IMAC or Interim MACs was discontinued by the Federal-Provincial-Territorial Committee on Drinking Water in 2003.
2. Turbidity guidelines are 0.3/1/0.1 NTU depending on whether you have a conventional treatment/slow sand or diatomaceous earth filtration/membrane filtration, respectively.
Review of the data Is based on the 1 NTU guideline.
3. Operation guidance value for conventional treatment plants, the guideline is 0.2 mg/L for all others.
4. 1992 and 1997 analytical results from the Associated Engineering Letter Re: Well 1-92 Rehabilitation Well Contamination Risk Assessment, dated June 13, 2002.
5. 2003 analytical results from Cantest analysis report for Group Number 41121063.
6. 2004 analytical results from Cantest analysis report for Group Number 50528053.
7. 2009 analytical results from Maxxam analysis report, Job#A930217.
8. 2010 analytical results from Maxxam analysis report, Job#B049027.
9. 2011 analytical results from Maxxam analysis report, Job#B167989.

Shaded box indentifies result exceeding CDWQ MAC.

Unshaded box identifies result exceeding CDWQ AO.

* These results cannot be compared to the guidelines either due to the fact the detection limit exceeds the guideline or due to the fact that the data has been reported as a greater than result.

TABLE 5 - Water Quality Data for Village of Pemberton Water System

Location	CDWQ MAC[1]	CDWQ AO	Well 1-92	Well #1	Well 2-97	Well 2-97	Well 2-97	Well #2	Well #2	Well #2	Well #3	Well #3	Well 3
Test Date			1992[4]	7/26/2011[9]	1997[4]	2003[5]	May-04[6]	6/16/2009[7]	6/21/2010[8]	7/26/2011[9]	6/16/2009[7]	6/21/2010[8]	7/26/2011[9]
Total Metals													
Aluminum (Al)	0.1[3]		<0.02	<0.003	<0.2*	0.008	<0.005	0.012	0.005	0.010	0.012	0.007	0.008
Antimony (Sb)	0.006		-	<0.0005	-	-	-	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Arsenic (As)	0.010		<0.001	<0.0001	>0.0001*	<0.001	<0.001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Barium (Ba)	1		0.011	0.033	<0.01	0.015	0.014	0.018	0.026	0.032	0.018	0.009	0.010
Boron (B)	5		<0.008	<0.050	-	<0.05	<0.05	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Cadmium (Cd)	0.005		0.004	<0.00001	<0.0002	<0.0002	<0.0002	0.00002	0.00002	0.00003	0.00001	0.00001	0.00001
Calcium (Ca)			5.81	11.1	6.62	9.11	-	8.98	14.2	15.8	9.02	5.39	5.24
Chromium (Cr)	0.05		<0.002	<0.001	<0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt (Co)			<0.003	0.0007	-	<0.001	-	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Copper (Cu)		1	<0.001	0.0008	<0.01	<0.001	0.001	0.0028	0.0167	0.0053	0.0005	0.0046	0.0186
Iron (Fe)		0.3	0.062	10.2	<0.03	<0.05	<0.05	0.006	0.014	0.025	<0.005	0.014	0.015
Lead (Pb)	0.01		<0.001	<0.0002	<0.001	<0.001	<0.001	0.0002	0.0019	0.0014	<0.0002	0.0010	0.0014
Magnesium (Mg)			0.29	0.56	0.34	0.56	0.53	0.43	0.80	0.86	0.44	0.30	0.27
Manganese (Mn)		0.05	0.012	0.282	<0.005	0.005	0.005	0.002	0.019	0.048	0.002	0.002	<0.001
Mercury (Hg)	0.001		<0.00005	<0.00005	<0.0005	<0.02*	<0.02*	<0.00002	0.00004	<0.00005	<0.00002	<0.00002	<0.00005
Molybdenum (Mo)			<0.004	<0.001	-	<0.0005	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (Ni)			<0.008	<0.001	-	0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	0.002
Phosphorus (P)			<0.04	-	-	0.05	-	-	-	-	-	-	-
Potassium (K)			<0.4	1.39	<2	0.76	-	0.81	1.29	1.46	0.81	0.58	0.55
Selenium (Se)	0.01		-	<0.0001	<0.0005	<0.001	<0.001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Silicon (Si)			3.85	-	-	10.9	-	-	-	-	-	-	-
Silver (Ag)			<0.01	<0.00002	-	<0.0001	-	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002
Sodium (Na)		200	1.32	3.96	<2	3.25	-	2.65	5.98	5.34	2.35	1.27	1.16
Strontium (Sr)			0.031	-	-	0.049	-	-	-	-	-	-	-
Sulphur (S)			-	3	-	-	-	<3	5	6	4	<3	<3
Tin (Sn)			<0.02	-	-	<0.001	-	-	-	-	-	-	-
Titanium (Ti)			<0.003	-	-	<0.001	-	-	-	-	-	-	-
Uranium (U)	0.02		0.0002	<0.0001	-	<0.0005	<0.0005	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Vanadium (V)			-	<0.005	-	-	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Zinc (Zn)		5	<0.002	<0.005	<0.005	<0.005	<0.005	<0.005	0.007	0.011	<0.005	<0.005	<0.005
Ryznar Index (RI)			12.1	-	12.4	-	-	-	-	-	-	-	-
Incrustation Potential Ratio (IPR)			<1	-	<1	-	-	-	-	-	-	-	-

Footnotes:

Concentrations are in milligrams per litre unless otherwise stated.

1. Summary of Guidelines for Canadian Drinking Water Quality, Health Canada, May 2008. MAC = Maximum Acceptable Concentration, AO = Aesthetic Objective.
 The use of IMAC or Interim MACs was discontinued by the Federal-Provincial-Territorial Committee on Drinking Water in 2003.
2. Turbidity guidelines are 0.3/1/0.1 NTU depending on whether you have a conventional treatment/slow sand or diatomaceous earth filtration/membrane filtration, respectively.
 Review of the data Is based on the 1 NTU guideline.
3. Operation guidance value for conventional treatment plants, the guideline is 0.2 mg/L for all others.
4. 1992 and 1997 analytical results from the Associated Engineering Letter Re: Well 1-92 Rehabilitation Well Contamination Risk Assessment, dated June 13, 2002.
5. 2003 analytical results from Cantest analysis report for Group Number 41121063.
6. 2004 analytical results from Cantest analysis report for Group Number 50528053.
7. 2009 analytical results from Maxxam analysis report, Job#A930217.
8. 2010 analytical results from Maxxam analysis report, Job#B049027.
9. 2011 analytical results from Maxxam analysis report, Job#B167989.

Shaded box indentifies result exceeding CDWQ MAC.

Unshaded box identifies result exceeding CDWQ AO.

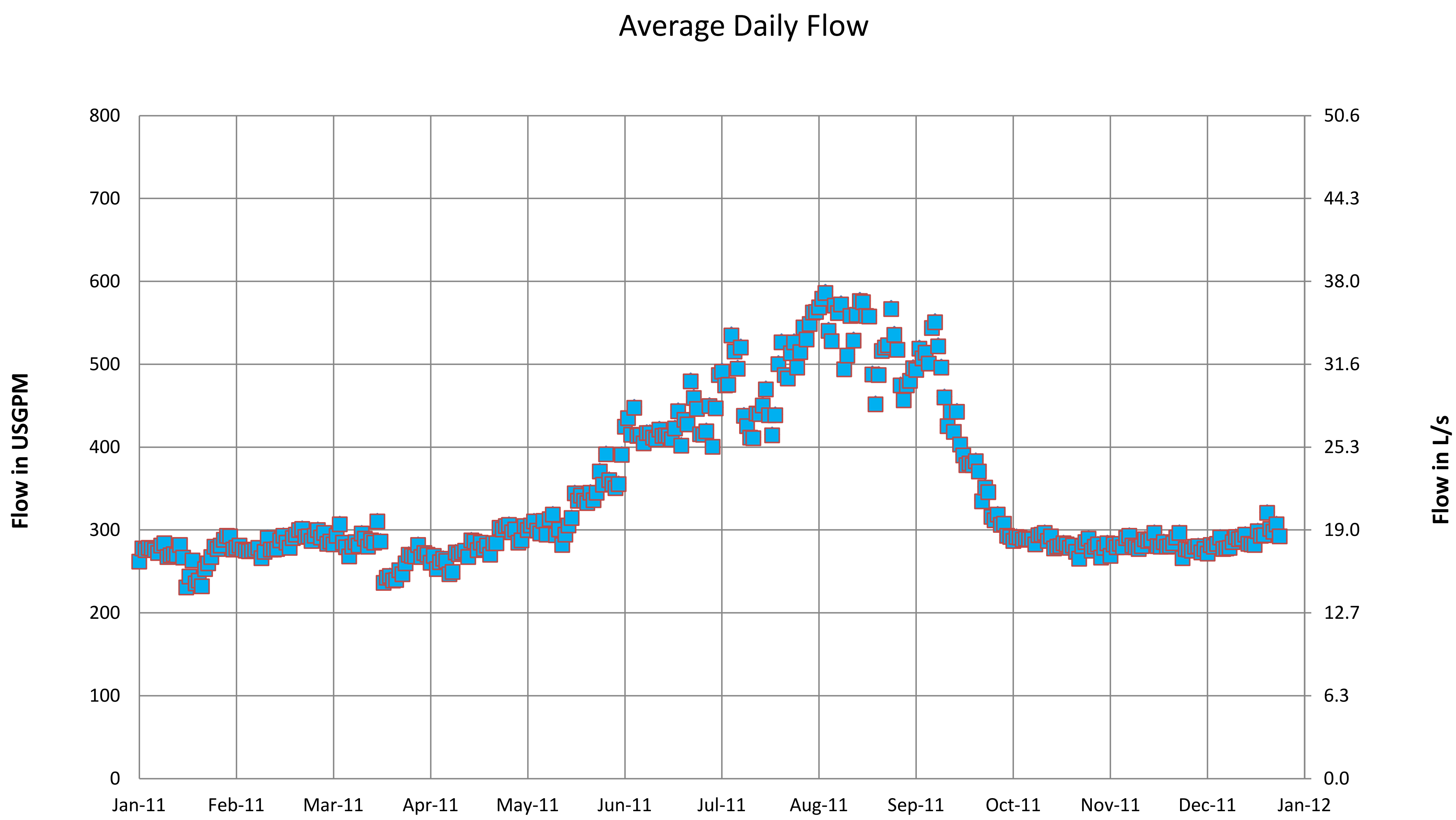
* These results cannot be compared to the guidelines either due to the fact the detection limit exceeds the guideline or due to the fact that the data has been reported as a greater than result.

APPENDIX A

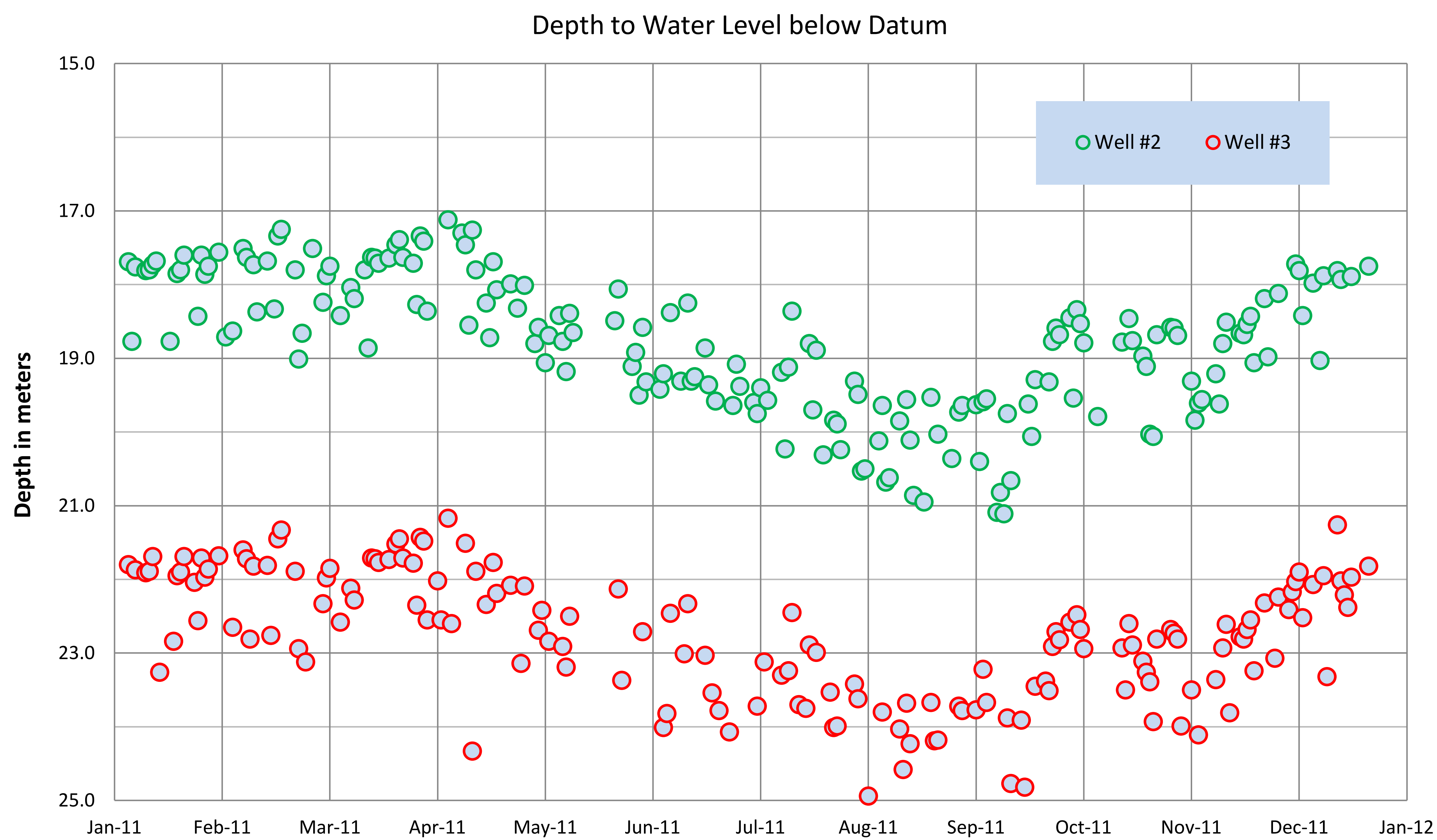
2011 FLOW, WATER LEVEL AND WATER QUALITY MONITORING DATA

FOR

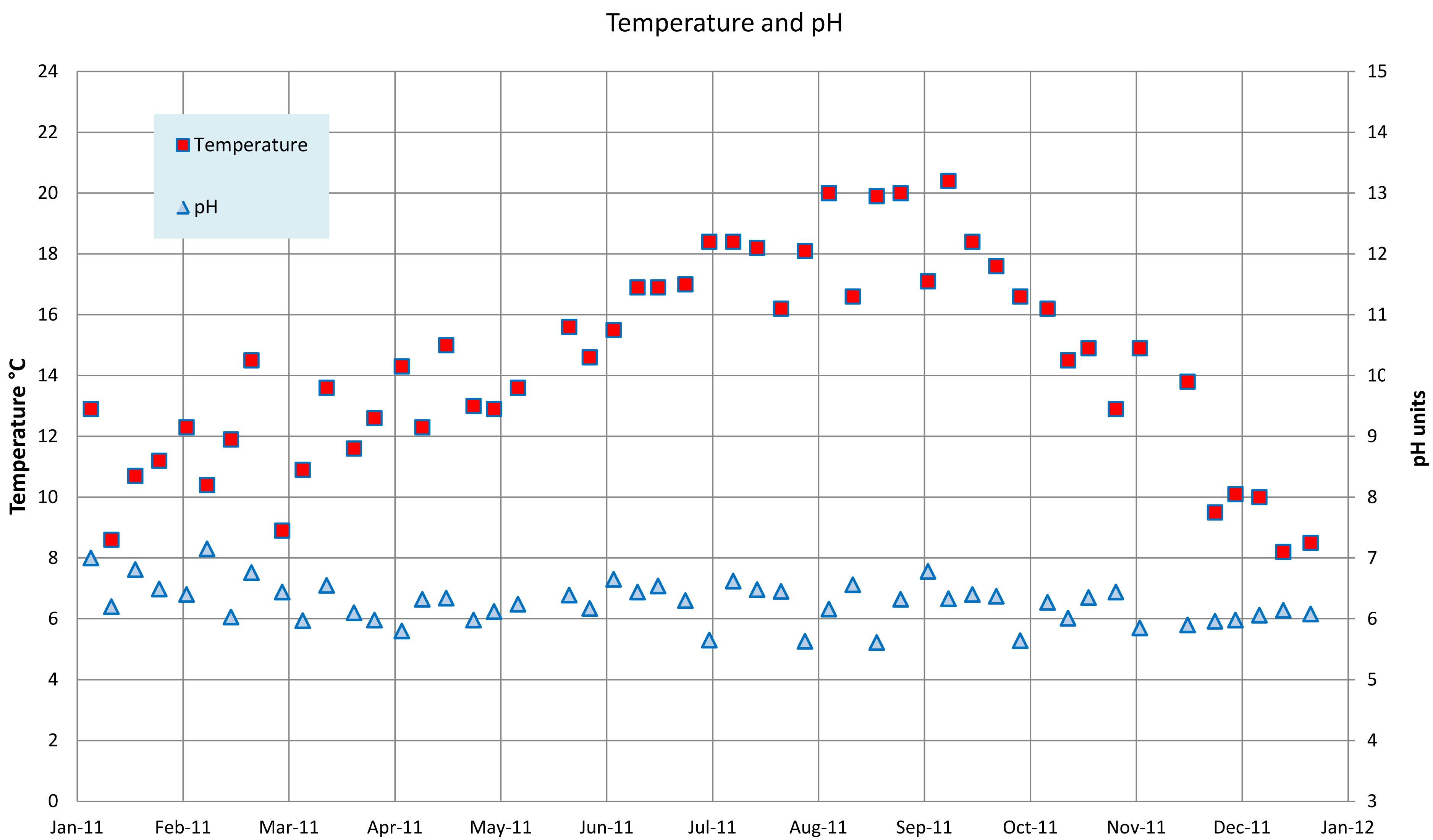
VILLAGE OF PEMBERTON WATER SYSTEM



Prepared By:	Client	Village of Pemberton	
Enterprise Geoscience Services Ltd.	Project	Well Protection Plan	
	Title	Average Daily Flow of Pemberton Water Supply System in 2011	
	Date	March, 2012	Figure A1



Prepared By:		
Enterprise Geoscience Services Ltd.	Client	Village of Pemberton
	Project	Well Protection Plan
	Title	Pemberton Water Supply System 2011 Water Levels in Well #2 and Well #3
	Date	March, 2012 — Figure A2



Note: Temperature and pH were measured at Village Office station

Prepared By:	Client	Village of Pemberton	
Enterprise Geoscience Services Ltd.	Project	Well Protection Plan	
	Title	Pemberton Water Supply System 2011 Water Temperature and pH	
	Date	March, 2012	Figure A3

APPENDIX B

WELL LOGS FOR

VILLAGE OF PEMBERTON WATER SYSTEM

PEMBERTON PRODUCTION WELL NO. 1

Location: In the Village of Pemberton on the south side of Aster Street, south of the Hotel.

Date of construction: February 1992.

Contractor: Field Drilling Contractors Ltd.

Driller's litholog:

0 - 4.3 m (0 - 14 ft)	loose sand and gravel
4.3 - 7.9 m (14 - 26 ft)	brown silty sand and gravel, making water
7.9 - 10.7 m (26 - 35 ft)	brown silty gravel and sand with pieces of wood; making some water with a static level of 2.1 m (7 ft)
10.7 - 11.6 m (35 - 38 ft)	very dirty silty gravel and sand with clay
11.6 - 18.0 m (38 - 59 ft)	cemented sand and gravel with wood; drilled open hole
18.0 - 20.1 m (59 - 66 ft)	compact sand and gravel
20.1 - 22.9 m (66 - 75 ft)	brown sand and gravel, water-bearing
22.9 - 25.9 m (75 - 85 ft)	brown finer sand with gravel
25.9 - 29.0 m (85 - 95 ft)	brown and grey silty sand, drilled open-hole.

Diameter: 200 mm (8") with 5.0 m (16½ ft) of 250 mm (10") diameter surface casing.

Static water level: On February 7, 1992, prior to the start of pump testing, 9.43 m (30.93 ft) below the 200 mm (8") diameter well casing stickup of 0.75 m (2.45 ft) above ground.

PEMBERTON PRODUCTION WELL NO. 1 (cont'd)

Completion:

The Pemberton Production Well is completed with the following assembly of 200 mm (8") nominal size Johnson stainless steel well screen:

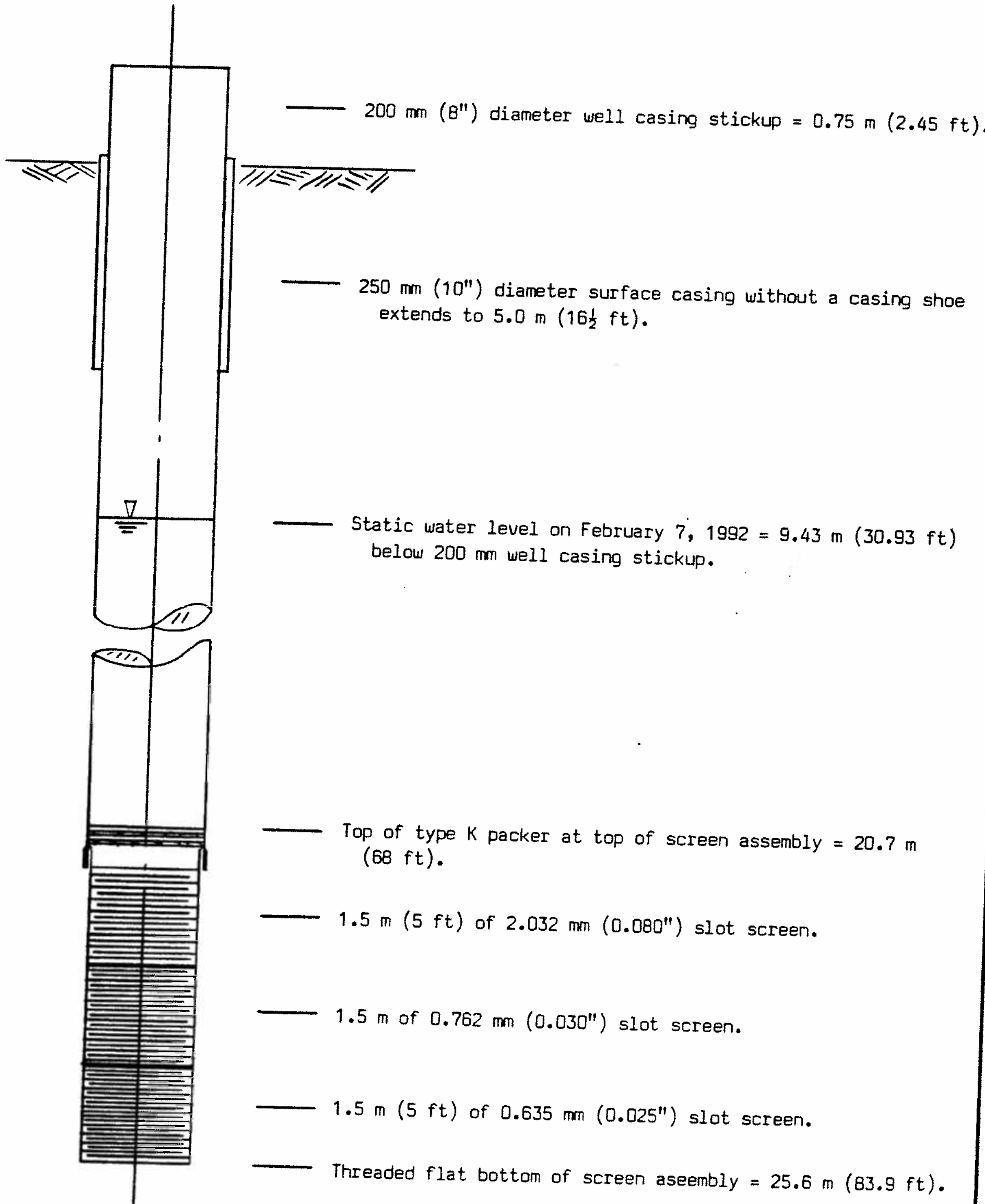
at top at 20.7 m (68.0 ft)	type K packer
1.5 m (5 ft) of	2.032 mm (0.080") slot screen
1.5 m (5 ft) of	0.762 mm (0.030") slot screen
1.5 m (5 ft) of	0.635 mm (0.025") slot screen
at bottom at 25.6 m (83.9 ft)	threaded flat bottom.

Measurements are below ground at the time of well construction.

Well performance: On February 8, 1992, after 24 hours of pumping, mostly at the final rate of 28.77 L/sec (456 USgpm), the maximum drawdown was 5.04 m (16.53 ft) for a specific capacity of 5.72 L/sec/m (27.64 USgpm/ft)

Well capacity: Based on well performance (specific capacity) projected from pump testing at a rate of 28.77 L/sec (456 USgpm), and based on use of the usual 70% of total available drawdown, the capacity of the Pemberton Production Well is theoretically as much as 45.9 L/sec (610 igpm; 730 USgpm).

FIGURE 3	PEMBERTON PRODUCTION WELL CONSTRUCTION DETAILS



Notes:

1. The sketch is not to scale.
2. The screen is 200 mm (8") nominal diameter Johsnon stainless steel.
3. All measurements are below ground unless otherwise indicated.

VILLAGE OF PEMBERTON PRODUCTION WELL 2-97

Location: In the Village of Pemberton, in the north-central part of Lot 11, north of Aster Street between Prospect and Frontier Streets.

Date of installation: April-May 1997.

Contractor: Perry's Well Drilling.

Driller's litholog:

0.0 - 5.2 m	(0 - 17 ft)	silty gravel
5.2 - 15.2 m	(17 - 50 ft)	sand and gravel; loose
15.2 - 20.4 m	(50 - 67 ft)	sand and gravel; compact
20.4 - 30.8 m	(67 - 101 ft)	sand and gravel; loose
30.8 - 32.0 m	(101 - 105 ft)	sand and gravel; compact
32.0 - 33.2 m	(105 - 109 ft)	sand and gravel; loose
33.2 - 36.3 m	(109 - 119 ft)	sand and gravel; compact
36.3 - 38.7 m	(119 - 127 ft)	sand and gravel; loose
38.7 - 41.8 m	(127 - 137 ft)	sand and gravel; finer; compact.

Diameter: 300 mm (12"), with 4.6 m (15 ft) of 400 mm (16") diameter surface casing; the annular opening between the casings is filled with bentonite grout.

Completed depth: 41.8 m (137 ft).

Static water level: 7.205 m (23.64 ft) below the well casing stickup, extending 0.81 m (32") above ground, prior to the start of step-drawdown test of May 21, 1997.

Completion: Pemberton Well 2-97 is completed with a 6.9 m (22.6 ft) long assembly of 300 mm (12") nominal diameter Johnson stainless steel well screen, as follows:

at top at 34.9 m (114.4 ft)	k-type packer
0.6 m (2 ft) of	250 mm (10") diameter riser pipe
4.9 m (16 ft) of	6.35 mm (0.250") slot screen
1.2 m (4 ft) of	2.54 mm (0.100") slot screen
at bottom at 41.8 m (137 ft)	threaded flat bottom.

Measurements are below ground at the time of well installation.

Well performance: Final constant-rate pumping of Pemberton Production Well 2-97 at 76 *l*ps (1205 USgpm) resulted in maximum drawdown of 11.96 m (39.24 ft) after 1440 minutes, for a specific capacity of 6.35 *l*ps/m (30.7 USgpm/ft). Projecting the trend of drawdown at the end of pumping to 100-days of continuous pumping at 76 *l*ps gives a drawdown of 17.67 m (58 ft), for a specific capacity of 4.30 *l*ps/m (20.8 USgpm/ft).

Well capacity: The projected 100-day drawdown of 17.67 m (58 ft), when pumping at 76 *l*ps (1205 USgpm), represents use of about 62% of the total available drawdown in the well. Therefore, the capacity of Well 2-97 for long-term community water supply is at least the test rate of 76 *l*ps. If, in future, plans call for pumping the well at a rate greater than 76 *l*ps, the performance of the well at the planned higher rate of pumping should first be confirmed by additional high-rate testing.

Province of British Columbia — Ministry of Environment — Water Management Branch

WATER WELL RECORD

Date 97 5 26 (YR MO DY)

NTS MAP ______ WELL No. ______ ELEV ______ Location Accuracy ______

UTM Z ______ E ______ N ______ UTM Date 19__ Well Type ______

Owners Name & Address: VILLAGE OF PEMBERTON

Legal Description & Address: LOT BEHIND HOTEL.

Descriptive Location ______

1. TYPE OF WORK 1 ☑ New Well 2 ☐ Reconditioned 3 ☐ Deepened 4 ☐ Abandoned

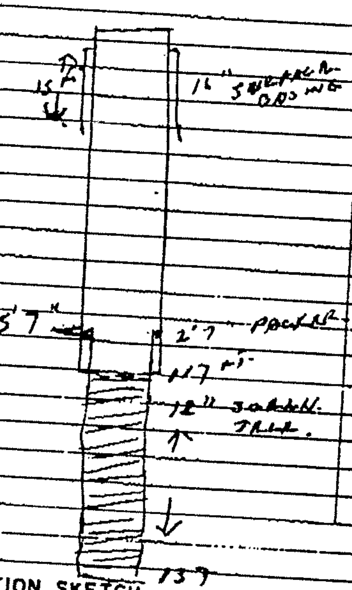
2. WORK METHOD 1 ☑ Cable tool 2 ☐ Bored 3 ☐ Jetted 4 ☐ Rotary a ☐ mud b ☐ air c ☐ reverse ☐ Other

3. WATER WELL USE 1 ☐ Domestic 2 ☑ Municipal 3 ☐ Irrigation 4 ☐ Comm. & Ind. ☐ Other

4. DRILLING ADDITIVES ______

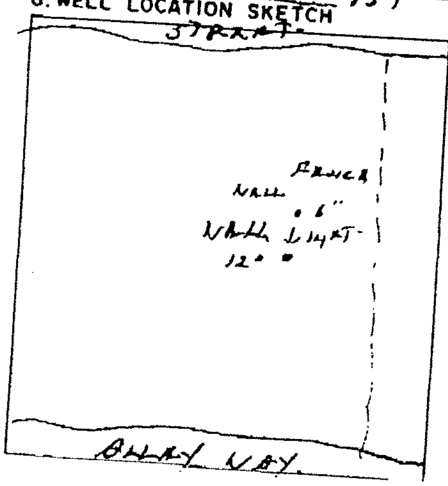
5. MEASUREMENTS from 1 ☐ ground level 2 ☐ top of casing; casing height above ground level ______ ft.

FROM ft	TO ft	6. WELL LOG DESCRIPTION	SWL ft
0	17	SILTY GRAVEL.	
17	50	SAND & GRAVEL	
50	67	TIGHT. PACKED SAND + GRAVEL	
67	101.	SAND + GRAVEL. WASH	
101	127	SAND + GRAVEL. TIGHT.	
127	137	SAND + GRAVEL TIGHT -	



7. CONSULTANT ______ Address ______

8. WELL LOCATION SKETCH



9. CASING: Materials 1 ☑ Steel 2 ☐ Galvanized 3 ☐ Wood 4 ☐ Plastic 5 ☐ Concrete ☐ Other

		units
Hole Diameter		ins
Diameter	12"	ins
from	+ 18"	ins
to	117'6"	ft
Thickness	.364	ft
Weight		ins
		lb/ft

Pitless unit ______ ft 1 ☐ above 2 ☐ below ground level

1 ☐ Welded 2 ☐ Cemented 3 ☐ Threaded | 1 ☐ New 2 ☐ Used

Perforations: ______

Shoe (s): GOOD R.

Open hole, from ______ to ______ ft Diameter ______ ins

Grout: ______

10. SCREEN: 1 ☑ Nominal (Telescope) 2 ☐ Pipe Size

Type 1 ☑ Continuous Slot 2 ☐ Perforated 3 ☐ Louvre ☐ Other

Material 1 ☑ Stainless Steel 2 ☐ Plastic ☐ Other

Set from 117 to 137 ft below ground level

RISER, SCREEN & BLANKS			units
Length	4 ft	16 ft	ft
Diam. ID	12" TELE.	12" TELE.	ins
Slot Size	100	250	ins
from	133	117	ft
to	137	133	ft

Fittings, top 2" RISER bottom FLAT BTM

Gravel Pack WITH K PACKER

11. DEVELOPED BY: 1 ☑ Surging 2 ☐ Jetting 3 ☐ Air 4 ☑ Bailing 5 ☑ Pumping ☐ Other

12. TEST 1 ☑ Pump 2 ☐ Bail 3 ☐ Air Date 97 5 21

Rate 200 USgpm Temp ______ °C SWL before test 23'7" ft

Water Level 54.8 ft after test of 24 hrs

☐ DRAWDOWN in ft				☐ RECOVERY in ft			
mins	WL	mins	WL	mins	WL	mins	WL

13.

RECOMMENDED PUMP TYPE	RECOMMENDED PUMP SETTING	RECOMMENDED PUMPING RATE
	ft	USgpm

14. WATER TYPE: 1 ☑ fresh 2 ☐ salty 3 ☑ clear 4 ☐ cloudy

colour ______ smell ______ ; gas 1 ☐ yes 2 ☐ no

15. WATER ANALYSIS: 1 Hardness ______ mg/L 2 Iron ______ mg/L 3 Chloride ______ mg/L 4 pH ______

Field Date ______ Lab Date ______ (YR MO DY)

SITE ID No ______

16. FINAL WELL COMPLETION DATA

Well Depth ______ ft Well Yield ______ US gpm

Static Water Level ______ ft Artesian Flow ______ US gpm Pressure Head ______ ft

Back filled ______

Well Head Completion ______

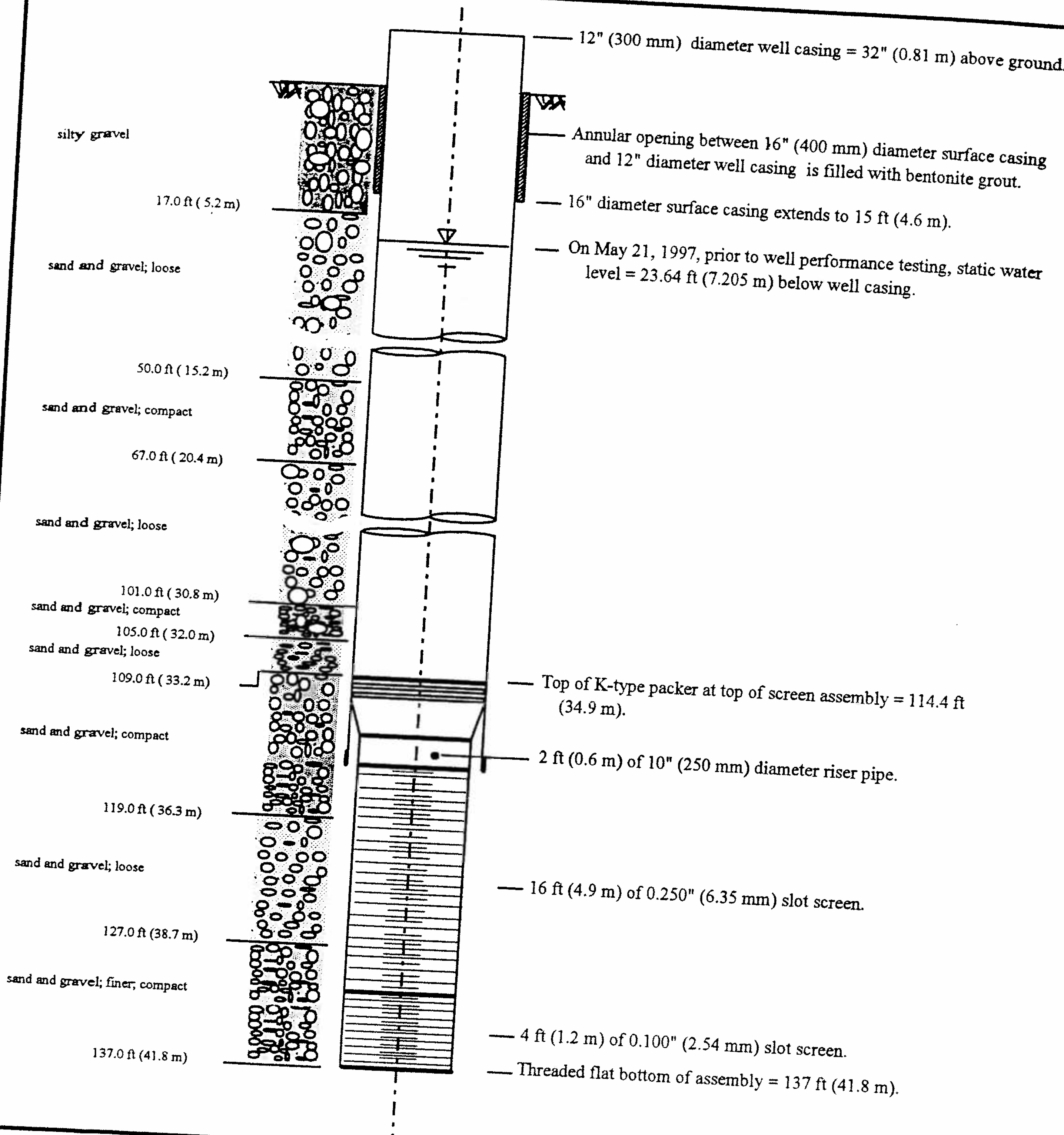
17. DRILLER (PLEASE PRINT) Surname: PERRY First Name: MARTIN

Signature [signature]

18. CONTRACTOR, Address

PERRY'S WELL DRILLING
1708 - 197 A Street
RR #1, Langley, B.C.
V2Z 1K2 Ph: 534-1347

Member, BCWWDA ☑ yes ☐ no ;



Notes:

1. Sketch is not to scale.
2. The well screen is 300 mm (12") nominal diameter Johnson stainless steel, of 264 mm (10.375") i.d..
3. All measurements are below ground unless otherwise indicated.

PROJECT NO: P718101

PROJECT:

VILLAGE OF PEMBERTON GROUNDWATER SOURCE DEVELOPMENT

LOCATION: Pemberton, B.C.

PACIFIC HYDROLOGY CONSULTANTS
CONSULTING HYDROGEOLOGISTS

WELL 2-97 CONSTRUCTION DETAILS

DATE:	BY:	FIGURE:
12/12/97	ab	3

APPENDIX C

SCREENING CHECKLIST FOR GARP/GWUDI ASSESSMENT

Figure 2: Screening Tool Checklist for Ground Water at Risk of Containing Pathogens

Water System Name: Village of Pemberton	**BCMOE Well ID Plate No.:** 815
Site location: Well # 1 Pemberton, BC	**Well Log Examined (Y/N):** Y
	Site Survey Conducted (Y/N): Y

RISK FACTORS and CRITERIA	YES: Potentially At Risk	NO: Low Risk	Comments
1. WATER QUALITY RESULTS			
1.1: Water system or well bacteriological sampling shows recurring presence of confirmed total coliform, fecal coliform, or *E.coli.*		✓	1 detection of total coliform in 130 samples (2009–2011)
1.2: Water system has historical turbidity issues associated with the source water.	✓		possibly iron bacteria
2. SOURCE TYPE and LOCATION			
2.1: Well situated inside setback distances of the *HHR*, from possible source of contamination.		✓	
2.2: Well with intake depth < 15 m below ground and located in floodplain / flood-prone area OR well located < 100 m outside the high water mark or natural boundary of surface water feature and intake depth < 15 m below the high water level		✓	
3. WELL CONSTRUCTION			
3.1: Well does not meet *GWPR* (section 7) for surface sealing.	JB ~~✓~~	✓	grouted surface casing to 5 m depth, pre-dates GWPR
3.2: Well does not meet *GWPR* (section 10) for well caps and covers.		✓	
3.3: Well does not meet *GWPR* (section 11) for floodproofing.		✓	
3.4: Well does not meet *GWPR* (section 12) for wellhead protection.		✓	
4. AQUIFER TYPE and SETTING			
4.1: Well with intake depth < 15 m below ground and situated in a sand and/or gravel unconfined aquifer or fractured bedrock aquifer.		✓	
4.2: Well completed in a karst bedrock aquifer.		✓	

Risk / Vulnerability Assessment Decision Taken & Reason(s): Well #1 only used for emerg. backup. No history of total ~~of~~ coliform or E. Coli. Well is in floodplain, but protected by dykes	
Action Recommendation: Stage 2	
Checklist / Assessment completed by: J. Balfour	**Date completed:** Apr 16/12

Figure 2: Screening Tool Checklist for Ground Water at Risk of Containing Pathogens

Water System Name: Village of Pemberton	**BCMOE Well ID Plate No.:** 816
Site location: Well #2, Pemberton BC	**Well Log Examined (Y/N):** Y
	Site Survey Conducted (Y/N): Y

RISK FACTORS and CRITERIA	YES: Potentially At Risk	NO: Low Risk	Comments
1. WATER QUALITY RESULTS			
1.1: Water system or well bacteriological sampling shows recurring presence of confirmed total coliform, fecal coliform, or *E.coli.*		✓	0 detections in 134 samples 2009-2011
1.2: Water system has historical turbidity issues associated with the source water.		✓	
2. SOURCE TYPE and LOCATION			
2.1: Well situated inside setback distances of the *HHR*, from possible source of contamination.		✓	Storage of plouged snow near wellhead?
2.2: Well with intake depth < 15 m below ground and located in floodplain / flood-prone area OR well located < 100 m outside the high water mark or natural boundary of surface water feature and intake depth < 15 m below the high water level		✓	
3. WELL CONSTRUCTION			
3.1: Well does not meet *GWPR* (section 7) for surface sealing.		✓	grouted between 16" + 12" casings to 4.6 m
3.2: Well does not meet *GWPR* (section 10) for well caps and covers.		✓	
3.3: Well does not meet *GWPR* (section 11) for floodproofing.		✓	
3.4: Well does not meet *GWPR* (section 12) for wellhead protection.		✓	
4. AQUIFER TYPE and SETTING			
4.1: Well with intake depth < 15 m below ground and situated in a sand and/or gravel unconfined aquifer or fractured bedrock aquifer.		✓	
4.2: Well completed in a karst bedrock aquifer.		✓	

Risk / Vulnerability Assessment Decision Taken & Reason(s): One of two primary source wells. No history of total coliform or E.Coli. Well located in floodplain but protected by dykes on Pemberton Creek	
Action Recommendation: Stage 2	
Checklist / Assessment completed by: J Balfour	**Date completed:** Apr 16/12

Figure 2: Screening Tool Checklist for Ground Water at Risk of Containing Pathogens

Plate No. not visible @ time of inspection

Water System Name: Village of Pemberton	**BCMOE Well ID Plate No.:**
Site location: Well #3, Pemberton BC	**Well Log Examined (Y/N):** N Not available
	Site Survey Conducted (Y/N): Y

RISK FACTORS and CRITERIA	YES: Potentially At Risk	NO: Low Risk	Comments
1. WATER QUALITY RESULTS			
1.1: Water system or well bacteriological sampling shows recurring presence of confirmed total coliform, fecal coliform, or *E.coli.*		✓	4 positive tests in 2009, none in 2010 or 2011. Positive total coliform in 2009 believed to be due to well commissioning in 2008. Total coliform detected in 2009, no E.coli.
1.2: Water system has historical turbidity issues associated with the source water.		✓	
2. SOURCE TYPE and LOCATION			
2.1: Well situated inside setback distances of the *HHR*, from possible source of contamination.		✓	
2.2: Well with intake depth < 15 m below ground and located in floodplain / flood-prone area OR well located < 100 m outside the high water mark or natural boundary of surface water feature and intake depth < 15 m below the high water level		✓	
3. WELL CONSTRUCTION			
3.1: Well does not meet *GWPR* (section 7) for surface sealing.			Probably adequate (drilled in 2008) but no log available.
3.2: Well does not meet *GWPR* (section 10) for well caps and covers.		✓	
3.3: Well does not meet *GWPR* (section 11) for floodproofing.		✓	
3.4: Well does not meet *GWPR* (section 12) for wellhead protection.		✓	
4. AQUIFER TYPE and SETTING			
4.1: Well with intake depth < 15 m below ground and situated in a sand and/or gravel unconfined aquifer or fractured bedrock aquifer.		✓	
4.2: Well completed in a karst bedrock aquifer.		✓	

Risk / Vulnerability Assessment Decision Taken & Reason(s): Well #3 one of two primary source wells commissioned in 2008. Well located in floodplain, but protected by dykes. Surface sealing probably meets GPR.	
Action Recommendation: Stage 2	
Checklist / Assessment completed by: J Balfour	**Date completed:** Apr 16/12