Phase 2: Groundwater Protection Study
District of Highlands

District of Highlands
Victoria, BC

Submitted to:

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Golder Associates

EXECUTIVE SUMMARY

This report presents the results of the second year (Phase 2) of a three-year Groundwater Protection Study (the "Study") being conducted by Golder Associates (Golder) on behalf of the District of Highlands (Highlands). The objectives of the Groundwater Protection Study are to assess groundwater conditions throughout the District, to provide the Highlands with information and tools to support the protection and conservation of groundwater quantity and quality and to guide future land-use decisions within the Highlands in light of potential impacts associated with climate change.

The scope of work for Phase 1 of the Study included developing a conceptual model of groundwater flow within the Highlands, constructing and calibrating a three-dimensional numerical groundwater flow model, compiling an inventory of unused water wells and developing recommendations for preliminary groundwater quality monitoring and groundwater level monitoring. The numerical model was used to conduct water balance analyses of the bedrock aquifer within the Highlands to assess the sustainability of current and future withdrawals, and potential effects of climate change. The numerical model was also used to delineate captures zones for select communal/commercial wells within the Highlands. The results of Phase 1 of the Study are presented in Golder's report titled "Phase 1: Groundwater Protection Study, District of Highlands" dated October 23, 2008 (Golder File No. 07-1414-0014).

The scope of work for Phase 2 of the Study consisted of conducting a contaminant inventory to identify potential sources of contamination to regional groundwater resources, developing preliminary recommendations for the conservation of groundwater quantity and the protection of groundwater quality, developing recommendations for public education, and implementation of a groundwater monitoring program to obtain water-level data and characterize groundwater quality related to general potability parameters.

Contaminant Inventory and Groundwater Protection Analysis

Data and information were collected through on-line searches, telephone enquiries and interviews, and a search of files maintained by the Highlands and Golder. The information consisted of land use zoning plans, business licenses, data from federal, provincial and municipal government sources, reports prepared by consultants, information collected from property owners and operators, and a site reconnaissance of select areas in the Highlands.

For the purposes of the contaminant inventory, the Highlands was categorized into three types of land use activities:

- Park and Rural Residential (P/RR);
- Commercial/Industrial (C/I); and,
- Comprehensive Development (CD).

Potential sources of groundwater contamination that are common to rural and rural residential properties within the P/RR category consist of septic systems, unused wells and active wells that are in disrepair, fuel storage tanks, the use, storage and disposal of chemicals and hazardous products, hobby farming activities, transportation routes and power transmission corridors. Residential-based businesses were identified at specific P/RR properties. Potential sources of groundwater contamination common to the types of respective businesses were discussed; the presence of business-related facilities (*i.e.*, workshops, equipment storage, etc.) was not verified at each of the properties.

A total of four C/I properties were identified in the southern portion of the Highlands and two C/I properties were identified immediately to the south, in the City of Langford. Of the six C/I properties identified, three of the properties are contained within the Ministry of Environment (MoE) contaminated sites registry, indicating that these sites have entered into the site assessment and remediation process. Environmental investigations and monitoring programs have been conducted on select C/I properties to assess potential contamination of the soils in specific areas and monitor groundwater quality in samples from select monitoring wells. Past and present land use activities on C/I properties may have contributed to groundwater contamination through the use, storage and disposal of fuels and motor oils, paints and solvents and other hazardous products, and burning of wastes.

Detailed records regarding the Bear Mountain Golf Course were not reviewed; however, potential sources of groundwater contamination associated with golf courses include the application, improper storage and/or disposal of fertilizers, pesticides and herbicides. Water from a proposed reclaimed (treated septage) water facility will be used to irrigate the golf course. Irrigation of the golf course with reclaimed water has the potential to introduce residual pharmaceuticals to the groundwater. Other potential sources of groundwater contamination on CD properties are inferred to be similar to those commonly associated with rural and rural residential properties.

Based on the results of the groundwater protection analysis, it is recommended that potential sources of groundwater contamination associated with past and present land use activities at C/I properties receive the highest priority for groundwater protection efforts. Use, storage and disposal of chemicals and hazardous products, septic systems, fuel storage tanks, and unused wells and active wells in disrepair should also be

prioritized for groundwater protection initiatives that are designed for implementation in rural and rural residential areas. The primary potential source of groundwater contamination in the area of the CD properties is the application, improper storage and/or disposal of fertilizers, pesticides and herbicides. There is a potential for residual pharmaceuticals to be introduced to groundwater through irrigation of the golf course with water from a proposed reclaimed (treated septage) water facility. It is also recommended that groundwater protection efforts address potential sources of contamination that are estimated to represent a relatively lower hazard to groundwater; these sources include hobby farms, transportation routes and power transmission corridors.

Preliminary Groundwater Protection Planning

Preliminary groundwater protection measures were developed to support the conservation of groundwater quantity and the protection of groundwater. These measures include groundwater level and water quality monitoring, public involvement initiatives, market approaches, technical assistance programs, hazardous waste collection programs, maintenance of a database of land uses, accidents and spills, and initiatives to support proper abandonment of unused wells that are located in areas of potential groundwater contamination.

Measures for groundwater protection will be further developed during Phase 3 of the Study to include initiatives for contingency planning for alternative water sources, emergency response planning and the protection of groundwater quantity through water conservation planning.

Recommendations for Public Education

It is recommended that public education initiatives on water conservation and groundwater quality protection be developed to supplement existing programs that are currently in place in the Highlands. Public education initiatives can be coordinated with the recommendations presented by the Highlands Sustainability Task Force, and the initiatives implemented by the Highlands Stewardship Foundation and the Highland District Community Association. It is recommenced that public education initiatives be further developed during Phase 3 of the Study. Golder will collaborate with the Groundwater Task Force to refine the content of the public education initiatives and support implementation of the initiatives with existing programs in the Highlands.

Preliminary Water Level Monitoring and Groundwater Quality Testing

During Phase 2 of the Study, monitoring wells were established at two locations and a preliminary water level monitoring and groundwater quality testing program was initiated. The program was expanded to include an additional eight locations by September 2009.

Detailed water level data were obtained from monitoring wells DOH-01 and DOH-02A, located in the central and western portions of the Highlands, respectively. Static water levels in DOH-01 were estimated to have declined approximately 4 metres between April and August, 2009. Water levels in DOH-02A were observed to decline by approximately 12 metres during the same period, suggesting a relatively stronger seasonal influence in the western portion of the Highlands.

The analytical results from the groundwater quality testing program are considered to be representative of general groundwater quality in the Highlands and characteristic of groundwater in a crystalline bedrock aquifer. Based on the analytical results, the groundwater in the bedrock aquifer is mineralized and relatively hard.

It is recommended that the groundwater monitoring program be expanded during Phase 3 of the Study to include the installation of pressure transducers in four more monitoring wells. It is also recommended that the Highlands continue to liaise with the CRD and site operators at C/I properties to identify and discuss opportunities to share information and coordinate groundwater monitoring efforts.

Recommendations

It is recommended that preliminary measures for groundwater protection be implemented to encourage conservation of groundwater quantity and the protection of groundwater quality. Coordination of the public education initiatives with existing programs in the Highlands would support implementation in an efficient and cost-effective manner.

Golder recommends that the Highlands maintain a database of specific land uses and significant accidents, fires or spills that may have occurred in the Highlands. Additional information is also required to supplement the results of the contaminant inventory and to assess the nature of on-site facilities and land use practices on properties where businesses and hobby farms have been identified. Further information regarding land use practices at the Bear Mountain Golf Course is required to confirm the priority ranking that has been assigned to land use activities associated with the golf course.

It is recommended that the water level monitoring program be expanded to include the deployment of pressure transducers in monitoring wells located in the southern, western, eastern and northern portions of the Highlands. The installation, operation and monitoring of flow meters on specific communal/commercial wells and a selection of privately owned domestic wells will provide more representative estimates of groundwater consumption in the Highlands. The detailed water-level and groundwater consumption data would support refinement of the numerical model and calibration of the model for prediction of transient conditions.

It is further recommended that the Highlands engage in discussions with the CRD and site operators at C/I properties to discuss opportunities to share information and coordinate groundwater monitoring efforts. It is recommended that the private water supply wells that are currently sampled on a quarterly basis by the CRD for analysis of light and heavy extractable petroleum hydrocarbons (LEPH and HEPH) and polycyclic aromatic hydrocarbons (PAHs) are also sampled and analyzed for concentrations of volatile organic compounds (VOCs), including benzene, toluene, ethyl benzene and xylene (BTEX).

GLOSSARY OF ACRONYMS

AFRP	All Fun Recreation Park
ALR	Agricultural Land Reserve
APEC	area of potential environmental concern
AST	above ground storage tank
BCWQG	BC Water Quality Guidelines
BTEX	benzene, toluene, ethyl benzene and xylene
CALA	Canadian Association for Laboratory Accreditation
CD	Comprehensive Development
C/I	Commercial/Industrial
CL	commercial land use
COA	certificate of analysis
CRD	Capital Regional District
CSR	Contaminated Sites Regulation
CSR AW	Contaminated Sites Regulation Aquatic Life (Water) Standard
DQO	data quality objective
EA	Environmental Assessment
EMA	Environment Management Act
EPH	extractable petroleum hydrocarbon
GCDWQ	Guidelines for Canadian Drinking Water Quality
GWPR	Ground Water Protection Regulation
HDCA	Highland District Community Association
HEPH	heavy extractable petroleum hydrocarbon
HSF	Highlands Stewardship Foundation
HSTF	Highlands Sustainability Task Force
IL	industrial land use
LEPH	light extractable petroleum hydrocarbon
MIP	Millstream Industrial Park
MoA	Ministry of Agriculture

MoE	Ministry of Environment
MSDS	materials safety data sheet
OCP	Official Community Plan
ORP	oxidation-reduction potential
PAHs	polycyclic aromatic hydrocarbons
PCOC	potential contaminant of concern
P/RR	Parks/Rural Residential
PSI	preliminary site investigation
QA/QC	quality assurance and quality control
RPD	relative percent difference
TCLP	toxicity characteristic leaching procedure
UST	underground storage tank
VIHA	Vancouver Island Health Authority
VOCs	volatile organic compounds
VPH	volatile petroleum hydrocarbon

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1.0 INTRODUCTION

This report presents the results of the second year (Phase 2) of a three-year Groundwater Protection Study (the "Study") conducted by Golder Associates Ltd. (Golder) on behalf of the District of Highlands (Highlands). The Phase 2 tasks were completed in accordance with the scope of work outlined in Golder's letter titled "*Revised Scope of Work Proposed for Phase 2 of the Groundwater Protection Study, District of Highlands*", dated April 14, 2009 (Golder file number 07-1414-0014, E/09/125).

This report should be interpreted and used in accordance with the limitations and considerations set out in the Golder Associates Ltd. *Limitations and Use of this Report*, which appears in Section 7.0.

1.1 Background and Objectives

The Highlands is one of 13 member municipalities of the Capital Regional District (CRD), encompassing approximately 37 square kilometers and located northwest of Victoria, BC (Figure 1). The majority of the residential population of approximately 2,010 obtains potable water from private, individual water wells. The River's Crossing development and the Hanington Creek Estates subdivision, located along the southern portion of the Highlands, obtain water from a communal well. Groundwater supplies within the Highlands are derived primarily from drilled wells completed in a bedrock aquifer. Sewage servicing within the Highlands is by individual septic systems.

Concerns have been raised over groundwater quantity and quality, particularly in relation to current and future development and land use. In 2007, the Highlands retained Golder to conduct a Groundwater Protection Study to assess groundwater conditions throughout the District, to provide the Highlands with information and tools to support the protection and conservation of groundwater quality and quantity, and to guide future land-use decisions within the Highlands in light of potential climate change impacts. The Study was designed to be delivered over a period of three years, in the following phases:

- Phase 1 – Data Compilation and Water Balance Analysis
- Phase 2 – Contaminant Inventory and Preliminary Groundwater Protection Planning
- Phase 3 – Groundwater Monitoring and Detailed Groundwater Protection Planning

The results of Phase 1 of the Study are presented in Golder's report titled "Phase 1: Groundwater Protection Study, District of Highlands" dated October 23, 2008 (Golder File No. 07-1414-0014). This current report presents the results of Phase 2 of the Study. Details on the individual tasks proposed for Phase 3 of the Study are outlined in Golder's work plan dated September 20, 2007 (Golder file number P7-1414-0014, E/07/434). Phases 1 and 2 of the Study were completed with input and direction from the Highlands Groundwater Task Force, a team comprising a staff member of the Highlands Municipal Office, a member of the Highlands Council and three volunteer residents. It is anticipated that the Groundwater Task Force will continue to guide the completion of Phase 3 of the Study.

1.2 Scope of Work

The scope of work that was defined for Phase 2 of the Study includes the following tasks:

- **Task 1** – Contaminant Inventory: Available information, including groundwater and environmental studies, land use zoning plans and business licenses, was assembled and reviewed; telephone inquiries and interviews were conducted with municipal and government officials; and a site reconnaissance of select areas of the Highlands was conducted to identify potential sources of contamination to regional groundwater resources.

- **Task 2** – Preliminary Groundwater Protection Planning: Preliminary recommendations for the conservation of groundwater quantity and the protection of groundwater quality were developed.

- **Task 3** – Recommendations for Public Education: Potential public education initiatives were identified to emphasize the importance of groundwater conservation and to provide measures that can be taken at the household and community-level to protect the resource. Opportunities to coordinate the groundwater public education efforts with existing programs in the Highlands were presented.

- **Tasks 4 and 5** –Groundwater Monitoring Program: A groundwater monitoring program was implemented to obtain water-level data from designated monitoring wells and collect and analyze water samples for general potability parameters. Strategic monitoring well locations were identified for the collection of additional water-level data and recommendations for the analysis of additional water quality parameters were presented;.

- **Task 6** – Draft Report: The results of Phase 2 of the Study are presented in this draft report and provided to the Groundwater Task Force for review.

- **Task 7** – Final Report: Upon receiving comments from the Groundwater Task Force, Golder will finalize the report for Phase 2 of the Study and provide hard copies and electronic copies of the final report to the Highlands.

- **Task 8** – Meetings: Golder representatives participated in a project progress meeting with the Groundwater Task Force on May 4, 2009. Golder representatives who are assigned to the Groundwater Protection Study also attended a meeting between representatives of the Highlands (the Mayor of the Highlands and members of the Groundwater Task Force) and the CRD project team involved with remediation activities at the Millstream Meadows property. It is expected that representatives from the Golder team will provide a presentation of the Phase 2 results in a District of Highlands Committee of the Whole Council Meeting to provide an opportunity for public response and input.

The results of Tasks 1 to 5 are presented in Sections 2.0 through 5.0 of this draft report and recommendations are provided in Section 6.0.

2.0 TASK 1 – CONTAMINANT INVENTORY

The objectives of the contaminant inventory and associated groundwater protection analysis were to identify:

- Past, current and future land uses activities where potential groundwater contamination may occur, and,

- The types of potentially hazardous substances stored and used by residents and local businesses that may affect groundwater quality in the Highlands.

The results of the contaminant inventory, in conjunction with the results of the water balance analyses (Phase 1), will provide the framework for developing recommendations for groundwater protection planning. The following sections present the methodology employed to compile the contaminant inventory, the results of the contaminant inventory and a relative ranking of the potential hazards to the groundwater resources in the Highlands.

2.1 Methodology

The contaminant inventory was focused on the area within the boundaries of the Highlands. However, relevant information was also collected for adjacent jurisdictions, including the Town of View Royal and the City of Langford. Data and information were collected by means of:

- A review of land use zoning plans and business licenses;

- On-line searches, including a search of the Contaminated Sites Registry (https://www.bconline.gov.bc.ca/) maintained by the BC Ministry of Environment (MoE) and the Canada411^{TM} telephone directory (http://www.canada411.ca/);

- Telephone inquiries and interviews with municipal and provincial government officials from the Highlands (including the Planner, Subdivision Approving Officer, Building Inspector and Fire Chief), the Capital Regional District (CRD) (officials with Parks and Water Services), the Vancouver Island Health Authority (VIHA) (Environmental Health Officer), the Ministry of Agriculture (MoA) (Senior Manager and Agrologist), BC MoE (Groundwater Protection Officer) and BC Parks;

- A search of files maintained by the Highlands, including inter-municipal business licenses;

- A search of files maintained by Golder; and,

- A site reconnaissance of select areas of the Highlands.

The contaminant inventory was conducted as an overview assessment of potential sources of contamination associated with regional groundwater resources, with consideration of localised land use activities, for the purposes of developing appropriate groundwater protection measures. The contaminant inventory did not include re-analysis of original data provided in previous reports, nor did it include site-specific inspections of individual properties. A summary of the information that was collected for review is presented in Table 1, at the end of this report.

2.2 Results

The Highlands Official Community Plan (OCP) was reviewed to assess the intended primary use of land within the District (District of Highlands, 2007). In general, land use in the Highlands consists primarily of park and rural residential land, with relatively more intensive residential development and commercial/industrial properties in the southern portions of the District. The OCP categorizes the Highlands into eight (8) land use designations. For the purposes of the contaminant inventory, the land use designations presented in the OCP were broadly grouped into three general land use categories on a geographic basis:

- Park and Rural Residential;

- Commercial/Industrial; and,

- Comprehensive Development.

The geographic extents of these general land use areas are presented on Figure 2.

Available information was reviewed and potential sources of groundwater contamination were identified. The results of the contaminant inventory are discussed in the following sections.

2.2.1 Parks and Rural Residential (P/RR)

The majority of the land within the District of Highlands is categorized as Parks and Rural Residential (P/RR) for the purposes of the contaminant inventory and includes parcels of land identified in the OCP under the following land use designations:

- Parks;
- Rural;
- Rural Residential;
- Managed Forest; and,
- Institutional.

Most of the land use in the P/RR designation is for park, rural and rural residential purposes.

Parks

The locations of parks within, and adjacent to, the Highlands are presented on Figure 2. Parcels of land within the Highlands that are designated as parks are under the jurisdiction of the Province of BC, the Capital Regional District (CRD) or the Highlands. Golder conducted telephone interviews with representatives of BC Parks, CRD Parks and the Highlands Municipal Office to assess current land use practices at parks in the Highlands. Golder contacted Mr. Joe Benning, Area Supervisor for Saanich and the Southern Gulf Islands, BC Parks, to discuss Gowlland Tod Provincial Park and Mr. Jeff Ward, Manager, CRD Parks, to discuss regional parks in the Highlands (*i.e.*, Mount Work, Lone Tree Hill and Thetis Lake Regional Parks). Highlands Municipal staff provided information on park land that is under the jurisdiction of the Highlands.

The primary uses of parks within the Highlands are for the purposes of conservation and outdoor recreation (Highlands, 2007). The majority of the park land is undeveloped, with some sports fields. BC Parks, CRD Parks and the District of Highlands do not store or maintain equipment, irrigate, or use pesticides or fertilizers on park lands located within the Highlands. No equipment is stored or maintained at the parks.

Existing structures and facilities in the parks generally comprise relatively small gravel parking lots and park signage. Mr. Ward advised that the CRD plans to construct a new gravel parking lot at the south end of Mount Work Regional Park (Figure 2). The

proposed parking lot is located in an area of sensitive vegetation that is designated as Development Permit Area No. 3 in the OCP. It is understood that an overview environmental assessment (EA) is currently being carried out to support an application for a Development Permit to construct the parking lot facility.

Potential sources of groundwater contamination associated with parking lots include spills or localized leakage of fuels, oil or other fluids. There is a greater potential for the infiltration of contaminants and/or contaminated storm water into the subsurface beneath gravel parking lots due to the higher permeability of gravel when compared to surfaces such as asphalt or concrete. Mr. Ward advised that the CRD maintains a database of incidents such as spills of deleterious substances and was not aware of any reported incidents on CRD park lands within the Highlands.

Pit toilets are located in the south parking area for Gowlland Tod Provincial Park, at the end of Caleb Pike Road, and at McKenzie Bight, along Finlayson Arm. Mr. Benning, of BC Parks, advised that the toilets comprise sealed culverts that are designed to be water-tight. The toilets are pumped out as needed; no chemicals are used in the toilet facilities. The parking lot that is proposed for Mount Work Regional Park will also include a pit toilet facility.

The Caleb Pike Heritage Park is located at 1589 Millstream Road. The park comprises five buildings and an orchard on a three (3) acre parcel. The park facilities are used by the Highlands Municipality for community events and are also available to the public for private rental. A groundskeeper resides in one of the buildings at the park and maintains the grounds. Equipment and materials that are stored and used at the park are inferred to be similar to those typically found at a rural residential property (*i.e.*, lawn mower, tools, etc.). It is understood that no pesticides or fertilizers are used at the park.

Rural and Rural Residential

Rural and rural residential properties in the Highlands are identified on Figure 2. Golder reviewed existing information and conducted a field reconnaissance to assess potential sources of groundwater contamination generally associated with rural land use. The results are presented in the following sections.

Common Sources of Groundwater Contamination

Potential sources of groundwater contamination that are common to rural and rural residential properties include:

- Septic systems;
- Unused wells and active wells that are in disrepair;
- Fuel storage tanks;
- Use, storage of and disposal of chemicals and hazardous products;
- Hobby farming; and,
- Transportation routes and power transmission corridors.

These potential sources were not assessed on an individual lot basis, but rather identified as sources that may contribute to general groundwater contamination in rural and rural residential areas of the Highlands.

Septic Systems

Private septic systems can be potential sources of groundwater contamination for microbes (*i.e.*, bacteria, viruses, etc.), nitrates, detergents, oils and chemicals. Groundwater contamination may result if septic systems are poorly sited, designed, constructed or maintained. Groundwater contamination may also occur in areas where the density of septic systems is high and the cumulative discharge from the septic systems exceeds the renovative capacity of the subsurface. The mortality of microbes in groundwater increases as subsurface travel time is extended and, in general, increasing the travel time between wells and sewage fields provides a corresponding reduction of risks associated with potential effluent contamination of wells. However, it is generally accepted that fractured bedrock aquifers have very limited, if any, ability to reduce microbe contamination in groundwater, despite travel times exceeding the stipulated values. If deleterious and/or hazardous substances such as oils, chemicals or certain pharmaceuticals are disposed of in a septic system that is not designed to treat these substances, the effluent from the septic system may introduce these harmful substances to groundwater resources.

Highlands Bylaw No. 154 presents standards for regulating the subdivision or development of land within the Highlands (Highlands, 2007). Rural and rural residential lots in the Highlands are serviced by on-site individual ground sewage disposal systems. *Section S-Standards for Sanitary Sewage Systems* outlines requirements for sewage disposal systems, including design input from a qualified Professional Engineer, compliance with the *Capital Health Region On-Site Sewage Disposal Guidelines* and the *Health Act*, and other specific requirements outlined in the Highlands Bylaw. Operation and maintenance of septic systems are the responsibility of the individual property owners.

Failure of a septic system is typically identified when effluent from a system discharges to the surface (*i.e.*, daylights) or when the quality of the water from a nearby well is impacted. Golder contacted Mr. Michael Riefman, Environmental Health Officer with the Vancouver Island Health Authority (VIHA), to inquire about groundwater quality in the Highlands and the performance of local septic systems. Mr. Reifman advised that the VIHA has limited information on file regarding domestic septic systems and water quality in the Highlands. VIHA has reviewed water quality data for the community supply well for the Hanington Creek Estates Subdivision and the River's Crossing development; no water quality issues were identified by the VIHA at those locations.

Unused Wells and Active Wells that are in Disrepair

Unused wells that are improperly abandoned and active wells that are poorly constructed, poorly sited or not maintained can act as direct conduits for the migration contaminants from the surface and shallow subsurface (*i.e.*, effluent from sewage disposal systems) to underlying aquifers. Preferential pathways can form along the outside of well casings that are corroded or completed with an insufficient surface seal. The ground surface in the vicinity of the well should be graded such that surface water drains away from the wellhead.

The *Ground Water Protection Regulation* (GWPR) [BC Reg. 299/2004; includes amendments up to BC Reg. 91/2009, March 6, 2009] provides guidance on groundwater protection measures including requirements for completion of wells with an adequate surface seal and placement of well caps and well covers, and measures for floodproofing and wellhead protection. The GWPR also provides guidance on deactivation and closure of wells.

During Phase 1 of the Study, an inventory of unused water wells was compiled in the Highlands water wells database. A total of 38 properties in the Highlands were identified where one or more unused wells were reported to be present; the locations of unused wells were identified on 32 properties (Golder, 2008).

A well survey was conducted by Highlands staff of 101 water wells in the Highlands (Franz, 2005). The results of the survey were compiled in the Highlands database. Out of the 101 wells surveyed, the presence of an adequate sanitary surface seal was verified for 19 of the wells and the ground surface was reported to slope away from 75 of the wells.

Fuel Storage Tanks

Leakage from fuel storage tanks can represent a significant threat to groundwater quality. The risk associated with fuel storage tanks can be reduced with secondary containment provisions (berms and/or double walled tanks) and management practices including monitoring and maintaining reconciliation records.

During the site reconnaissance, above ground storage tanks (ASTs) were noted at some private residences. The ASTs were inferred to contain propane or heating oil. Underground storage tanks (USTs) may also be present at private residences. Leakage from ASTs can usually be detected from visual observations and/or odours. However, contamination from USTs may persist for some time before the leakage is identified either through fuel loss or evidence of subsurface contamination (*i.e.*, in one or more nearby wells). Therefore, USTs can pose a greater threat to groundwater resources than ASTs.

The Highlands Municipal Office does not maintain records of fuel tanks at private residences within the Highlands. Therefore, the number of oil tanks in the Highlands was not evaluated, and the ages and conditions of existing tanks were not assessed.

Use, Storage and Disposal of Chemicals and Hazardous Products

Private residences may contribute to groundwater contamination through improper use, storage and disposal of chemicals and hazardous products, including fuels and motor oils, paints and solvents, disinfectants and cleaning products, and other hazardous products. Storage and application of lawn and garden chemicals (*i.e.*, fertilisers, pesticides and/or herbicides) at private residences may also represent a potential threat to groundwater resources. These products may represent a greater threat to groundwater resources if storage and use (*i.e.*, equipment maintenance, fuelling, etc.) is near a wellhead.

Hobby Farming

Potential groundwater contamination typically associated with agricultural practices can result from the storage and use of animal manure and the application of chemical fertilisers and pesticides. Environmental issues related to agriculture are regulated according to the *Code of Agricultural Practice for Waste Management* [am. BC Regs. 321/2004, s.2; 377/2008, Sch. Ss. 2 and 3] by the *Agricultural Waste Control Regulation* [BC Reg. 131/92; includes amendments up to BC Reg. 377/2008, December 9, 2008] under the *Environmental Management Act* [SCB 2003; Chapter 53]. Other regulations applicable to the agricultural industry include the *Integrated Pest Management Act* [SBC 2003; Chapter 58] (formerly the *Pesticide Control Act*) which regulates the use of pesticides, and the *Farm Practices Protection (Right to Farm) Act* [RSBC 1996; Chapter 131], which regulates issues related to noise, odour and dust.

Some hobby farms are located on rural residential properties; no land within the Highlands is located within the Agricultural Land Reserve (ALR) and no commercial farms are present. The Highlands have no specific guidelines for farms, but encourages residents to follow good practices that are consistent with existing regulations.

Mr. Rob Kline, Regional Agrologist with BC MoA, advised that a land use inventory for the Highlands has not been compiled by MoA. Mr. Kline noted that potential impacts to groundwater from agricultural activity are expected to be relatively low as waste (*i.e.*, manure) management and application of fertilisers and pesticides are limited in the Highlands. Concentrations of phenolic compounds may be relatively higher in runoff from wood chips at equestrian riding rings.

Transportation Routes and Power Transmission Corridors

Stormwater runoff from transportation routes commonly contains contaminants such as metals, oils, grease, antifreeze, gasoline and other petroleum, and biological constituents. These constituents can infiltrate into the subsurface and contaminate groundwater resources. Surface runoff in the Highlands is collected and transmitted through a network of unlined drainage ditches. It is understood that surface runoff that collects in the drainage ditches infiltrates into the subsurface.

Specific contamination events can occur due to spills of transported substances as a result of accidents along transportation routes. The Highlands Municipal Office advised that roads in the Highlands are mainly used for residential traffic and there are no designated trucking routes within the District.

Power transmission corridors extend through the southern portion of the Highlands (Figure 2). Information regarding maintenance of the power transmission corridors was not reviewed. Although the power transmission corridors are located on private land, it is understood that the corridors have traditionally been accessed for recreational purposes, including use of motorised recreational vehicles. Localised fuel spills and unauthorized dumping of refuse may occur along the power transmission corridors.

Specific Land Use Practices

In addition to the general items discussed above, specific land use practices in rural and rural residential areas of the Highlands were also assessed. Golder reviewed a list of intermunicipal business licenses that was provided by the Highlands Municipal Office. Intermunicipal licenses are issued to businesses that have an office in the Highlands but complete work in other municipalities. Golder supplemented this information with an on-line telephone directory search, interviews with Highlands Municipal staff and a general field reconnaissance. The objective of the field reconnaissance was to assess land use activities and business activities in the Highlands. The field reconnaissance did not include detailed site inspections of individual properties.

The majority of the businesses identified in the rural and rural residential areas of the Highlands were inferred to be located at private residences. The presence of business-related facilities (*i.e.*, workshop, equipment storage, etc.) was not verified at all properties during the field reconnaissance; detailed inspections would be required to confirm the presence or absence of business-related facilities at the individual properties.

The results of the data review and field reconnaissance were compiled and businesses that may have the potential to introduce contamination to groundwater resources were identified. The results are presented on Figure 2 and summarised below:

- Automotive: businesses related to automotive repairs, service, restoration or storage were identified at seven (7) properties; a shop or garage facility was observed at four (4) of these properties. Potential groundwater contamination from these facilities can result from spills and leaks of fuels, oils and automotive fluids, cleaning fluids, solvents, paints and other chemicals.

- Excavation or construction: five (5) businesses were identified. Business-related facilities were not observed at the listed properties during the field reconnaissance. Vehicle and equipment maintenance and fuelling activities have the potential to introduce contaminants such as oils and fuels, solvents, paints and automotive wastes (antifreeze, fluids, battery acid, etc.) to the subsurface.

- Metal recycling: one (1) metal recycling facility was identified and observed. Groundwater concerns include potential contamination of metals and other contaminants from materials that are stored at the site.

- Lawn care and landscaping: four (4) businesses related to lawn care, landscaping, tree service and top soil delivery were identified. Only residential buildings were observed at the listed properties during the field reconnaissance. Groundwater contamination from these activities may result if fertilizers, herbicides or pesticides are not stored or disposed of properly.

- Photography service: one (1) photography business was identified at a property that was observed to be a private residence. If stored and disposed of improperly, chemicals associated with photograph processing and development may infiltrate into the subsurface.

- Cabinetry and woodwork: woodworking businesses were identified at two (2) properties. A shop facility was observed at one of the properties. Potential contaminants of concern associated with woodworking facilities include wood strippers, paints and solvents, and release of phenolic compounds from treated wood.

- Painting: a sign painting business was identified at one (1) residential property. Improper use, disposal and storage of paints and solvents may result in groundwater contamination.

- Air conditioner repair and maintenance: one (1) business related to air conditioner repair and maintenance was identified. The presence of a shop or garage facility was not confirmed during the site reconnaissance. Spills or leaks of chemicals and refrigerant gas may represent a potential threat to groundwater resources.

Managed Forest

Lands are designated as Managed Forest in the OCP to maintain forestry as an economic activity in the Highlands and to encourage sustainable forest management practices (Highlands, 2007). Owners of property that is designated as Managed Forest are permitted to engage in forest management activities that are consistent with the *Private Managed Forest Land Act* [SBC 2003; Chapter 80]. However, Highlands Municipal staff advised that relatively little harvesting is occurring in the Highlands. Highlands Municipal staff also advised that a parcel of land in the central portion of the Highlands that is currently designated as Managed Forest has been transferred to CRD Parks.

Potential sources of groundwater contamination associated with harvesting activities relate to potential fuel spills and localised dumping. Alteration of the ground surface may alter local drainage characteristics and removal of overburden material may reduce the capacity of the overburden materials to attenuate contaminants before being transmitted into the underlying bedrock aquifer.

Institutional

Institutional properties located within the P/RR land use designation comprise the West Fire Hall at 1564 Millstream Road, the East Fire Hall at 3613 Woodridge Place and the District Municipal Office at 1980 Millstream Road (Figure 2).

Golder conducted interviews with the Fire Chief and Deputy Fire Chief of the Highlands Fire Department. Foam fire retardant and fuel, including diesel and gasoline, are stored at the fire halls; a detailed chemical inventory was not conducted. The foam fire retardant stored at the fire halls is Phos-chek® WD-881. A copy of the material safety data sheet (MSDS) is provided in Appendix I. The volumes of fuels stored at the fire halls were estimated to be less than 100 L. The fuel was stored in jerry cans.

The Deputy Fire Chief advised that drills involving fire suppression are conducted approximately twice per month at the west fire hall. The fire drills involve setting an old car body on fire in at a location that is adjacent to the fire hall. The area where the fire drills are conducted is not paved. During the drills, fuel is used as a fire accelerant. Golder understands that the volume of fuel used in the fire drills is approximately three to four gallons (approximately 10 to 15 L) per year. The Deputy Fire Chief also advised that minimal fire retardant is used during the drills and estimated that approximately 120 to 160 L of the retardant is used per year.

2.2.2 Commercial/Industrial (C/I)

Groundwater contamination can result from a number of different sources associated with commercial and/or industrial land use activities. Properties that are designated as Commercial/Industrial in the OCP are also categorised as Commercial/Industrial (C/I) for the purposes of the contaminant inventory (Highlands, 2007). Commercial/Industrial properties within the Highlands are located in the southern portion of the District and extend south into Langford (Figure 2). The C/I properties in the Highlands are currently used for activities that are permitted in the zoning bylaws.

Information pertaining to the C/I properties that was collected for review included data available on-line from provincial government sources, information collected from Highlands Municipal staff and reports prepared by consultants, as provided by the Highlands. Golder personnel also conducted a field reconnaissance to assess current land use at the C/I properties.

Golder conducted an on-line search of information available in the MoE Site Registry (https://www.bconline.gov.bc.ca/) to identify sites in the southern portion of the Highlands for which the Ministry retains environmental information. The site registry stores information with respect to contaminated properties and sites which have entered into the site assessment and remediation process (BC Online, 2009). The records in the registry are limited to information obtained since approximately 1989. The existence of a property within the site registry does not necessarily imply that the property is contaminated, under the existing *Contaminated Sites Regulation* [BC Reg. 375/96; includes amendments up to BC Reg. 343/2008, January 1, 2009]. The property registration process can be triggered by a number of mechanisms including surface contamination, property transactions and facility upgrades. Similarly, there may be a number of contaminated sites within the study area that have not been identified by the site registry.

A total of four C/I properties were identified in the southern portion of the Highlands and two C/I properties were identified immediately to the south in Langford. At each of the six properties, areas of potential groundwater contamination were identified based on a review of available information. The locations of the potential areas of groundwater contamination are presented on Figure 3 and the nature of the potential contaminants are summarized in Table 2, located at the end of this report, and discussed below. Of the six C/I properties, three of the properties are contained within the BC Online contaminated sites registry. The addresses for the registered sites are 1965 Millstream Road, 2000 Block of Millstream Road and 2015 Millstream Road. Summary reports of the registry search are provided in Appendix II and detailed reports for the three properties are provided in Appendix III.

As discussed in the following sections, a number of environmental investigations and monitoring programs have been implemented on certain C/I properties. Subsurface investigations have been conducted to assess potential contamination of soils in specific areas and environmental monitoring programs have been implemented to assess groundwater quality in samples from select monitoring wells. It is important to note that, as further discussed in Section 3.0, groundwater flow in bedrock aquifer systems is localised within structural discontinuities and fracture systems. Therefore, an absence of detectable contaminant parameters in samples from the wells that were monitored does

not necessarily indicate that contaminants are not present in adjacent fracture networks and/or other areas of the C/I properties.

Highwest Waste Management Facility (1943 Millstream Road)

The Highwest Waste Management Facility is currently operated at 1943 Millstream Road. Land use activities at the facility have included landfill for demolition waste, burning, chipping of wood waste, composting and soil remediation (Thurber, 2001). Golder interviewed Chew Excavating Ltd., the current operator of the facility, to discuss land use activities at the property. The facility is operated under a Waste Management Permit that was issued by the BC MoE (Chew Excavating, 2009). Authorised activities include controlled burning and operation of a landfill for waste, including demolition and earth materials, and vegetation. It is understood that Quantum Hazmat Inc. operates an active soil treatment cell at the property under a separate permit.

Contaminants that can be associated with past and current land uses at the property include metals, hydrocarbon parameters, such as light and heavy extractable petroleum hydrocarbons (LEPH and HEPH), polycyclic aromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs) including benzene, toluene, ethyl benzene and xylene (BTEX), and phenols. There is the potential for dioxins and furans to be generated at facilities where waste is burned.

An environmental monitoring program has reportedly been carried out at the property since 1995 (Golder, 2000). It is understood that the monitoring program comprises collection and analysis of water samples from surface water locations, relatively shallow monitoring wells at the property and three nearby residential water supply wells (Chew Excavating, 2009). Reports pertaining to the operations at the Highwest Waste Management Facility or the environmental monitoring program were not made available for review at the time of the Contaminant Inventory.

Millstream Meadows (1965 Millstream Road)

The Millstream Meadows property is registered with the contaminated sites registry. The record status for the property is “Active – Under Remediation” (Appendix III). Based on a review of the detailed report, 24 notations (*i.e.*, activities) are recorded for the property, beginning with registration of a lagoon in 1971 under the Pollution Control Act. The most recent notation was the submission of a notice of independent remediation that was initiated on July 31, 2008.

Quarrying activities are inferred to have occurred in the area of the Millstream Meadows property prior to 1908, as limestone is reported to have been produced from two quarries that were located on the east side of Millstream Road, south of Tenook Lake (Fischle, 1992). The property was operated as an unregulated septage disposal facility from approximately 1970 to 1984 (Golder, 2000). It is understood that, during that time, septage and other trucked liquid wastes, including oily wastes, were disposed of at the facility. Liquid wastes were discharged to two upper lagoons (Lagoons 1 and 2) and flowed by gravity into a lagoon that was at a lower elevation (Lagoon 3). The nature and volume of liquid waste disposed to the lagoons is unknown, but is thought to have included gasoline, diesel fuel, oil and other petroleum hydrocarbons. Other wastes reported to have been deposited at the facility include domestic garbage and industrial wood waste. When the facility ceased operation, the hydrocarbon wastes in Lagoons 1 and 2 were burned and the lagoons were filled with demolition waste and blast rock, and covered with a clay cap. Following closure of the lagoons, the property was reported to have been used as a storage facility for items including treated timbers, dock floats, bulk storage tanks, old fuel tanks and wastes. Unauthorised dumping of scrap metal, domestic garbage and other refuse is reported to have occurred at the property since closure of the lagoons.

Areas of the property that may contribute to groundwater contamination include the former septage lagoons, a location along the northern portion of the property where fill materials of unknown quality were inferred to have been deposited and localised areas along the southern portion of the property where domestic waste (*i.e.*, appliances, automobile parts, household garbage) was historically deposited (Table 2; Figure 3). Contaminants that may potentially be introduced to groundwater due to past land uses at the property include metals, hydrocarbon parameters (*i.e.*, LEPH, HEPH, PAHs, VOCs and BTEX), phenols from wood products, and dioxins and furans associated with burning activities.

A number of environmental investigations were carried out between 1995 and 2000 to assess soil and groundwater conditions at the property (Golder, 2007a). Boreholes were advanced and completed as groundwater monitoring wells at locations within, and adjacent to, the former lagoon areas and in areas where fill materials and domestic waste were inferred to have been deposited. Monitoring wells were completed at different depths to characterise groundwater conditions in the overburden materials and in the underlying bedrock. The results of the environmental investigations and monitoring program identified localised hydrocarbon-contaminated soil and groundwater in the vicinity of the former septage lagoons.

Commencing in 2000, a water quality monitoring program was implemented at the property on a semi-annual basis. Water quality samples were collected from select monitoring wells and surface water locations and analysed for hydrocarbon parameters including LEPH, HEPH, PAHs and BTEX. Water quality data from monitoring events carried out to the end of 2006 indicated that concentrations of the analysed parameters were generally less than the associated laboratory detection limits, with the results for a few parameters reported at concentrations that exceeded the BC Contaminated Sites Regulation (CSR) standards for Aquatic Life (AW) and Drinking Water (DW) (Golder, 2007a). One to two centimetres (cm) of free floating hydrocarbon product was historically observed in a monitoring well that was completed in overburden materials within the area of Lagoon 1.

In 2007, during a routine groundwater monitoring event, approximately 13 cm of free floating hydrocarbon product was observed in a monitoring well that was completed in fractured bedrock, at a location adjacent to the former septage lagoons (Golder 2007a). Prior to this sampling event, petroleum hydrocarbon constituents had been reported for samples from this monitoring well at concentrations below the associated laboratory detection limits.

In response to the results of the 2007 monitoring event, the CRD undertook measures to address potential water quality concerns of residents in the area of the Millstream Meadows property. As a precautionary measure, the CRD offered to test privately-owned domestic drinking water wells and water supply wells within a 1 km radius of the Millstream Meadows property and to provide complimentary bottled water to those residents (CRD, 2008a). Beginning in November 2007, water samples have been collected on a quarterly basis from twenty seven (27) wells and analysed for concentrations of LEPH, HEPH and PAHs; it is understood that these analytical parameters were selected in consultation with VIHA (CRD, 2009). As of October 2009, no detectable concentrations of the parameters analysed have been reported in the samples from wells on adjacent properties since testing began in November 2007 (CRD,2008b).

The CRD also installed additional monitoring wells at specific locations of the property, increased the frequency of the water quality monitoring program to a quarterly schedule and implemented a site remediation plan (CRD, 2008b). Excavation of contaminated soils was completed in November 2008. Excavated soils were tested and segregated, and contaminated soils were transported to appropriate facilities for treatment or disposal. Additional management steps were implemented, including securing the area of the excavation with fencing, diversion of surface water around the excavation, treatment of residual surface water in the excavation and enhanced groundwater monitoring. In 2009, supplemental site investigations were conducted to support the development of a

remediation completion plan and a Notice to Proceed was issued to backfill the excavation and to install a product recovery system (CRD, 2009). It is understood that the backfilling and installation of the product recovery system are scheduled to commence late in 2009.

REM 5, Millstream Road Site (PID 024-710-270)

The REM 5 property is located on the east side of Millstream Road, to the south and east of the Millstream Meadows property (Figure 3). The results of the BC Online site registry search identified records for the address identified as 2000 Block Millstream Road (Appendix III). Based on a review of the information contained in the detailed report, the property identified as 2000 Block Millstream Road is inferred to be the REM 5 property. The status of the property is "Inactive – No Further Action". Six (6) notations are recorded in the detailed report, beginning with a request for an internal review of a Preliminary Site Investigation (PSI) report in 2001 and ending with a request for a Certificate of Compliance under the Environmental Management Act (EMA), dated 6, 2005.

The property currently consists of second growth timber. Localised dumping of refuse is reported to have occurred along old logging trails (Thurber Environmental Consultants, 2001). Analytical results for a groundwater sample that was collected from a relatively deep bedrock well (98.5 m; 323 ft) that is located in the central portion of the property indicated toluene at concentrations that exceeded the drinking water guidelines; detectable concentrations of VOCs and PAHs were also reported for the sample. Following further well development, a subsequent water sample was collected and analysed. The results indicated the presence of detectable concentrations of toluene that were below the drinking water guideline.

Millstream Industrial Park (2015, 2023 Millstream Road)

Millstream Industrial Park (MIP) extends from 2015 Millstream Road in the Highlands to 2023 Millstream Road, in the City of Langford (Figure 3). The results of the BC Online site registry search identified records for the property located at 2015 Millstream Road (Appendix III). The detailed report indicates that the status of the property is "Active – Under Remediation". A total of nineteen (19) notations are recorded for the property, beginning with a request in 1990 for a Remediation Plan for the Hypo Bio Gas & Oil Ltd. facility. The most recent notation is a Site Profile Review, dated May 7, 2004.

The topography in the area of MIP is inferred to have been significantly influenced by quarrying activities and the placement of fill materials (Trow, 2005a). The majority of the industrial activity at the property is inferred to have commenced after 1968. Based on a review of information presented in available reports and the results of the field reconnaissance, twelve (12) different areas of potential groundwater contamination were identified for the purposes of the contaminant inventory (Table 2; Figure 3). Contaminants that could potentially be introduced to groundwater due to past and present activities at MIP generally include metals and hydrocarbon parameters (*i.e.*, LEPH, HEPH, PAHs and VOCs). Localised glycol contamination may result from improper use, storage and disposal of vehicle fluids. Dioxins and furans may have been generated in the area where a large tire fire was reported to have occurred. Areas of potential groundwater contamination for which additional information was available are discussed in more detail below.

A number of investigations were conducted to assess subsurface conditions in specific areas of MIP. An excavation and soil sampling program was conducted in 1999 in the vicinity of the former tire storage area and soil remediation cells (MIP 6 and 8; Table 2, Figure 3) (Orca, 1999). The results of the soil sampling program reported copper and zinc at concentrations higher than the CSR standards for Environmental Protection (toxicity to soil invertebrates and plants). The concentrations of hydrocarbon parameters in soil were less than the associated CSR criteria in the samples analysed.

Following completion of a Stage 1 Preliminary Site Investigation (PSI), two (2) Stage 2 PSIs were conducted in 2005 to assess subsurface conditions in the vicinity of the autowrecking facility (MIP 4; Table 2, Figure 3) and a fill area in the southern portion of MIP (MIP 7; Table 2, Figure 3) (Trow, 2005b; 2005c). Concentrations of certain metal parameters (antimony, arsenic, barium, cadmium, chromium, copper, lead, nickel, tin and zinc) were reported to be greater than the CSR standards for Commercial Land Use (CL) and/or Industrial Land Use (IL) in soil samples that were collected from the area of the autowrecking facility (MIP 4); concentrations of PAHs and glycols were reported at concentrations less than the CSR CL/IL standards.

Analytical results for soil samples that were collected in the southern fill area (MIP 7) indicated concentrations of metal parameters (antimony, arsenic, cadmium, chromium, copper, lead, nickel and zinc) at concentrations that were greater than the CSR CL/IL standards. Ethylbenzene, xylenes and volatile petroleum hydrocarbons (VPHs) were reported in one soil sample at concentrations that were greater than the CSR CL/IL standards. Groundwater samples were collected from two monitoring wells located in the southern fill area (MIP 7). The analytical results indicated the presence of lead and manganese at concentrations that exceeded the CSR DW standards; concentrations of

hydrocarbon parameters (VOCs, BTEX, VPH and extractable petroleum hydrocarbon; EPH) were less than the lab detection limits and the CSR DW standards.

Select soil samples that were collected from the area of the autowrecking facility (MIP 4) and the fill area in the southern portion of MIP (MIP 7) were also analysed using a Toxicity Characteristic Leaching Procedure (TCLP). The analytical results were less than the associated Hazardous Waste Regulation (HWR) Leachability standards, suggesting that soils in the areas sampled were not considered to be hazardous waste (Trow, 2005b & c). It was recommended that soils in the areas investigated were likely suitable for management on-site (Trow, 2005c).

A quarterly water quality monitoring program was implemented from 1998 through 2004 to assess the quality of groundwater and surface water at locations within MIP and along Millstream Creek (Orca, 1998, 2004). The monitoring program did not assess groundwater quality in all of the areas of potential groundwater contamination that were identified under previous environmental investigations. Groundwater samples were collected from six (6) relatively shallow monitoring wells located within MIP; the monitoring wells were reported to have been completed in unconsolidated materials (*i.e.*, the wells were not drilled into bedrock) at depths ranging from approximately 3 metres (m) to 7.9 m (10 ft to 26 ft) below ground surface (bgs). The compiled analytical results from 1998 through to the final event in 2004, as presented in the Fall 2004 Quarterly Monitoring Report, indicate that concentrations of metals reported for surface water and groundwater samples were generally below the associated British Columbia Water Quality Guidelines (BCWQGs) for the protection of Aquatic Life[1] (AW) during most events, with the exception of isolated occurrences of chromium and copper (Orca, 2004). Analytical results for VOC parameters, as presented in select reports from 1998, 1999, 2003 and 2004, were also reviewed. Concentrations of toluene and ethylbenzene were reported to be greater than the associated BCWQGs for Drinking Water (DW) in samples that were collected from monitoring wells and a surface water lagoon that were located in a fill area in the southern portion of MIP (MIP 7; Table 2, Figure 3). Concentrations of VOC parameters reported for samples collected in other areas of MIP were less than the BCWQGs for DW and generally below the laboratory detection limits.

[1] Included amendments to July 1999.

All Fun Recreation Park (2207 Millstream Road)

The All Fun Recreation Park (AFRP) is located to the south of MIP (Figure 3).

Current land use activities at the AFRP include a quarry operation in the western portion of the property, and an automotive racetrack (*i.e.*, speedway) and a recreation vehicle park in the northeastern and eastern portions of the property, respectively. A water slide facility was operated in the northern portion of the property; it is understood that the facility ceased operations following the summer of 2007. A paved parking lot is located in the central portion of the property. Recreation facilities including an electric go cart track, mini-golf and driving range are located in the southern portion of the AFRP property.

In the vicinity of the automotive racetrack, potential groundwater contamination may result from spills and leaks of fuels, oils and automotive fluids, cleaning fluids, solvents, paints and other chemicals. Spills or leaks of chlorine and other chemicals may have occurred in the vicinity of the water slides when the facility was operational.

2.2.3 Comprehensive Development (CD)

Land that is located in the southwestern portion of the Highlands is categorised as Comprehensive Development (CD) for the purposes of this Study. Land in the CD designation is predominantly characterised by the following land use designations (as per the OCP):

- Institutional;
- Intensive Residential;
- Recreation Tourism; and,
- Bear Mountain Comprehensive Development.

The CD designation also includes parcels of land that are identified as parks, rural and rural residential in the OCP. The land use designations for the individual properties within the CD category are presented in Figure 2.

The Highlands Municipal office is located on the property identified as Institutional, the Hanington Creek Estates subdivision is categorised as Intensive Residential and the River's Crossing development is located on the property that is designated for Recreation Tourism. The Bear Mountain Comprehensive Development is currently zoned for a golf

course, residential units, a hotel and resort, and some commercial facilities. The golf course has been constructed and is operational but the other facilities have not yet been built. Part of this development will include the construction and operation of a reclaimed (treated septage) water facility to irrigate the golf course. To the south of the Bear Mountain Comprehensive Development, in Langford, there exists a separate golf course, a hotel and resort, and commercial facilities.

Potential sources of groundwater contamination associated with the Highlands Municipal office, the Hanington Creek Estates subdivision and River's Crossing development are inferred to be similar to those presented for rural and rural residential properties; potential sources of groundwater contamination associated with rural and rural residential land uses are presented in Section 2.2.1.

Detailed records regarding the Bear Mountain Golf Course were not reviewed for the purposes of the contaminant inventory. Application, improper storage and/or disposal of fertilisers, pesticides and herbicides are potential sources of groundwater generally associated with golf courses. Improper use and storage of fuels and other chemicals may also represent a potential threat to groundwater resources. Once the proposed reclaimed water facility is operational, irrigation of the golf course with reclaimed, treated septage water has the potential to introduce residual pharmaceuticals to the groundwater. Requirements for groundwater monitoring are outlined in the Master Development Agreement (MDA) between the Bear Mountain Master Partnership (formerly LGB9 Development Corporation) and the District of Highlands (Highlands, 2005).

2.3 Summary

The Highlands was categorized into three broad, geographical areas of land use activity for the purpose of the contaminant inventory. The majority of land use within the Highlands can be characterized as Park and Rural Residential (P/RR), while the south central portion can be characterized as Commercial/Industrial (C/I) and the southwest corner of the Highlands can be characterized as predominantly Comprehensive Development (CD).

Potential sources of groundwater contamination that are common to rural and rural residential properties within the P/RR category include septic systems, unused wells and active wells that are in disrepair, fuel storage tanks, the use, storage and disposal of chemicals and hazardous products, hobby farming activities, transportation routes and power transmission corridors. Residential-based businesses at P/RR properties are categorized as automotive, excavation or construction, metal recycling, lawn care and landscaping, photography service, cabinetry and woodwork, painting and air conditioner

repair and maintenance; the presence of business-related facilities (*i.e.*, workshop, equipment storage, etc.) was not verified at all properties.

Past and present land use activities on C/I properties may have contributed to groundwater contamination through the use, storage and disposal of fuels and motor oils, paints and solvents and other hazardous products, and burning of wastes. Environmental investigations and monitoring programs have been conducted on select C/I properties to assess potential contamination of the soils in specific areas and monitor groundwater quality in samples from select monitoring wells.

Detailed records regarding the Bear Mountain Golf Course were not reviewed; however, potential sources of groundwater contamination associated with golf courses include the application, improper storage and/or disposal of fertilizers, pesticides and herbicides. Once the proposed reclaimed water facility is operational, irrigation of the golf course with reclaimed, treated septage water has the potential to introduce residual pharmaceuticals to the groundwater. Other potential sources of groundwater contamination on CD properties are inferred to be similar to those commonly associated with rural and rural residential properties.

Table 3 provides a summary of the potential hazards identified by the contaminant inventory and a relative ranking of those hazards, as a means of providing the Highlands with some guidance on prioritizing groundwater protection efforts.

Based on the results of the groundwater protection analysis, it is recommended that potential sources of groundwater contamination associated with past and present land use activities at C/I properties receive the highest priority for groundwater protection efforts. Use, storage and disposal of chemicals and hazardous products, septic systems, fuel storage tanks, and unused wells and active wells in disrepair should also be prioritized for groundwater protection initiatives that are designed for implementation in rural and rural residential areas. The primary potential source of groundwater contamination in the area of the CD properties is the application, improper storage and/or disposal of fertilizers, pesticides and herbicides. It is also recommended that groundwater protection efforts address potential sources of contamination that are estimated to represent a relatively lower hazard to groundwater; these sources include hobby farms, transportation routes and power transmission corridors.

Table 3
Potential Contaminant Hazards to Groundwater Resources
District of Highlands, BC

Potential Source of Groundwater Contamination	Priority Ranking	Area of Concern
Current commercial and industrial (C/I) activities	High from spills and incidental releases including equipment operation and maintenance, transfer and storage of fuels, waste oil and automotive fluids, active quarry operations, etc.	C/I properties in the southern portion of the Highlands
Existing contamination related to historical activities (C/I properties)	High from existing contamination including disposal of liquid wastes, burning and storage of waste and deleterious substances, operation of soil remediation cells, etc.	C/I properties in the southern portion of the Highlands
Use, storage and disposal of chemicals and hazardous products	Medium from spills, leaks or incidental releases on residential properties (including home-based businesses)	Residential properties in the Highlands and capture zones for communal/commercial wells
Septic Systems	Medium from incidental releases resulting from poor construction or maintenance and disposal of deleterious substances that system is not designed to treat	Residential properties in the RR/P and CD land use categories
Application of chemicals including fertilizers, herbicides or pesticides	Medium from improper application or incidental releases at golf course facilities	Capture zones for communal/commercial wells and properties in the CD land use category
Fuel Storage Tanks	Low to medium from incidental releases on residential properties where tanks do not have secondary containment provisions	Residential properties in the Highlands
Unused Wells and Active Wells in Disrepair	Low to medium from migration of contaminants from the surface to the subsurface	All properties in the Highlands
Hobby Farming	Low from waste management and potential application of fertilizers and pesticides	Specific properties within the P/RR areas of the Highlands

Potential Source of Groundwater Contamination	Priority Ranking	Area of Concern
Transportation Routes and Power Transmission Corridors	Low from stormwater runoff and from incidental releases along routes and corridors	Throughout the Highlands
Irrigation of Golf Course	Low from potential trace concentrations of residual pharmaceuticals in water from the proposed reclaimed water facility	Bear Mountain Comprehensive Development

3.0 TASK 2 – PRELIMINARY GROUNDWATER PROTECTION PLANNING

The detailed contaminant inventory was conducted across the Highlands to assess potential sources of groundwater contamination. The groundwater protection analysis considered land use activities within the capture zones that were predicted for communal/commercial groundwater users during Phase 1 of the Study (Golder, 2008). As discussed in Section 1.1, the majority of the residential population in the Highlands obtains potable water from private, individual water wells. Therefore, the groundwater protection analysis was also conducted with consideration of other areas of the Highlands where potential sources of groundwater contamination were identified. It is understood that the water supply wells identified at the MIP are not used for drinking water purposes.

The capture zones for the communal/commercial groundwater users and the locations of the wells in the Highlands database (project database) are presented on Figure 6. In general, the size of the capture zones were influenced by the estimated pumping rates of the wells, the presence of lineaments and well interference effects. The capture zones presented in Figure 6 were estimated based on bulk characteristics of the bedrock aquifer; however, groundwater flow in bedrock aquifer systems is localised within structural discontinuities and fracture systems. Groundwater that is pumped from the communal/commercial wells may be derived from areas outside the capture zones estimated by the model.

Based on the results of the contaminant inventory, a number of groundwater protection measures were developed. The following sections present a preliminary set of groundwater protection measures that can be implemented by the Highlands through regulatory (*i.e.*, zoning) and/or non-regulatory (*i.e.*, guidelines, public education, etc.) measures.

3.1 Water-Level and Groundwater Quality Monitoring

The preliminary groundwater monitoring program that was initiated during Phase 2 of the Study will continue during Phase 3 of the study. Golder recommends that the Highlands engage the operators of the communal/commercial wells to discuss opportunities to obtain water-level and water consumption data for the respective wells. It is also recommended that the Highlands contact the CRD to discuss opportunities to share water quality data from existing groundwater monitoring programs that are currently being implemented in the area of the C/I properties, in the southern portion of the Highlands. Recommendations for groundwater monitoring are discussed further in Section 5.0.

3.2 Public Involvement

Public involvement can be one of the most effective groundwater protection measures. Public involvement has two related components: public participation and public education (Golder, 1995). Public participation is the involvement of the community in the development and implementation of the groundwater protection plan. Public education is the provision of information to the public to create awareness of the importance of protecting groundwater resources, to reassure the public that their interests are protected and to educate the public about the steps that they can take to protect the resource. Recommendations for public education are discussed further in Section 4.0.

3.3 Market Approaches

Market approaches involve the use of taxes, subsidies and other financial mechanisms to encourage groundwater protection. Water conservation initiatives could assist in reducing the volumes of groundwater extracted from the bedrock aquifer and help offset potential impacts of future development and/or climate change. Golder proposes that the Highlands may wish to consider market approaches that encourage conservation related to both water use and energy consumption. The Highlands could consider financial incentive programs that encourage the use of water efficient toilets and appliances, rainwater harvesting, xeriscaping, and the use of flow meters on communal, commercial and/or domestic wells. The data collected with flow meters could be used to refine water consumption estimates used in the numerical model and would demonstrate a commitment to water conservation. It is understood that the Highlands Sustainability Task Force provided recommendations for market approaches in a report that has been submitted to Council.

3.4 Technical Assistance Programs

Technical assistance programs could be developed to enhance public awareness and education initiatives and provide property owners with information on ways to prevent groundwater contamination. Technical assistance programs could emphasize requirements for adequate wellhead protection (*i.e.*, surface seal, well caps and covers, floodproofing, etc.) and provide recommendations for regular inspection and maintenance of septic systems and storage tanks, spill protection and secondary containment systems for storage tanks, and outline appropriate storage practices for hazardous household chemicals.

Technical assistance programs could also be developed to provide support to property owners where specific land use practices have been identified for groundwater protection efforts. The Highlands could conduct a survey of the owners of properties where

businesses and hobby farms have been identified to discuss the nature of the on-site facilities and land use practices. Based on the results of the survey, the Highlands could provide information packages (brochures, web addresses, etc.) that provide recommendations specific to the respective land use practices.

Technical assistance programs can be implemented through a number of mechanisms including distribution of fact sheets and work sheets, hosting workshops and/or implementing home inspection programs. Existing technical assistance initiatives (*i.e.*, pamphlets, bulletins, etc.) that are currently being implemented by the Highlands could be reviewed to assess the effectiveness of the existing initiatives and identify opportunities for further development. The Highlands may also wish to explore opportunities to coordinate technical assistance initiatives with existing programs being implemented by other municipal, provincial and/or federal government programs. One such example is the BC Environmental Farm Plan Program that is a voluntary program designed to identify on-farm environmental risks and provide measures to address the risks (BC Agricultural Research and Development Corporation, 2009).

3.5 Hazardous Waste Collection

A hazardous waste collection program involves the collection of household hazardous wastes within groundwater protection areas. The objective of a collection program is to mitigate potential groundwater contamination due to accidental spills or inappropriate disposal of chemicals or wastes at households and businesses in the Highlands. A hazardous waste collection program could be developed and implemented by the Highlands that involves organization of a designated hazardous waste collection day or days once or several times per year, operation of a designated drop-off station, or a "mobile unit" program whereby vehicles travel to designated locations to collect hazardous waste. Potential legal issues associated with collection, transport and disposal of hazardous waste must be considered when developing a hazardous waste collection program.

3.6 Database of Land Uses, Accidents and Spills

It is recommended that the Highlands maintain a database of specific land uses and significant accidents on transportation routes and power transmission corridors in the Highlands. As discussed in Section 3.4, it is recommended that the Highlands conduct a survey of the owners of properties where businesses and hobby farms have been identified to assess the nature of the on-site facilities and land use practices. Further information regarding land use practices at the Bear Mountain Golf Course should also be gathered. The results of the land use surveys should be documented in a database. The database should also include details of accidents, spills or fires, including

documentation on hazardous materials that may have been released to the environment and, if possible, estimated volumes of hazardous materials that may have been released.

3.7 Well Abandonment

It is recommended that a review of the Highlands database be conducted to identify unused wells that are located in areas where potential sources of groundwater contamination were identified. Unused wells could be inspected and wells that are inferred to be relatively vulnerable to contamination could be properly abandoned in accordance with the measures outlined in the Groundwater Protection Regulation (GWPR).

4.0 TASK 3 – RECOMMENDATIONS FOR PUBLIC EDUCATION

As discussed in Section 3.0, public involvement can be one of the most effective groundwater protection measures. The objectives of Task 3 were:

- To provide support to existing public education initiatives regarding groundwater conservation and protection; and,

- To provide recommendations for the development and implementation of additional initiatives that create awareness of the importance of groundwater conservation and protection and to educate the public about measures that can be taken to protect groundwater resources.

Golder proposes to further develop the public education initiatives in Phase 3 of the Study. Golder will collaborate with the Groundwater Task Force to refine the content for the public education initiatives and identify opportunities to coordinate the initiatives with existing programs in the Highlands to support implementation in a cost-effective manner.

4.1 Methodology

Golder presented the results of Phase 1 of the Study to members of the Highlands Council, municipal staff and members of the public at a Committee of the Whole council meeting on October 27, 2008. The presentation provided an opportunity to communicate the results of the Study to the public. It is anticipated that Golder will also present the results of Phases 2 and 3 of the study to Highlands Council members, municipal staff and members of the public.

Golder provided support to the Highlands in composing text for articles in the Highlands Community Newsletter and technical support for the development of the Highlands Green Map. In support of the informative map, Golder provided a diagram that was modified from Phase 1 of the Study and illustrates groundwater flow in the Highlands. Golder also provided suggestions on the content of the supporting text.

Golder attended a meeting with the Groundwater Task Force on May 4, 2009 to review project progress and discuss further opportunities for public education. During the meeting, the content for proposed public education initiatives was discussed and existing initiatives in the Highlands and other municipalities (*e.g.*, Gulf Islands) were identified. Golder, with input from the Groundwater Task Force, developed a preliminary framework of recommendations for public education initiatives related to groundwater conservation and protection in the Highlands.

4.2 Results

Based on the results of the May 4, 2009 meeting, it was recommended that the content of public education initiatives be developed with consideration to the results of both the water balance (Phase 1) and the contaminant inventory (Task 1, Phase 2). Public education initiatives should emphasize the importance of conservation of groundwater and provide measures that can be taken at the household and community level to protect the resource.

Opportunities for coordinating public education efforts regarding groundwater resources with existing programs in the Highlands include:

- Highlands Sustainability Task Force (HSTF): the HSTF was created to recommend initiatives that support the sustainability of the community; a final report has been submitted to Council and will be discussed early in 2010. Groundwater initiatives can be incorporated into a comprehensive conservation program that contains provisions for conservation related to water use and energy consumption. Such a conservation program could include the introduction of cost-saving incentive programs, changes to bylaws and taxing formulas to encourage water conservation and the production and distribution of educational materials.

- Highlands Stewardship Foundation (HSF): the HSF is a volunteer, community-based initiative that promotes the principles of lake stewardship. It is recommended that the Highlands coordinate groundwater initiatives with the activities of the HSF to encourage consideration of the complete water cycle. It is understood that surface water monitoring programs are conducted by volunteers. The Highlands may wish to consider providing capacity building support to the HSF to include groundwater monitoring programs in the future.

- Highland District Community Association (HDCA): the HDCA provides opportunities for social, cultural and educational activities. The HDCA organizes a number of events and activities each year including an annual community cleanup, a guest speaker series, public information sessions and a number of events for children. The Highlands may wish to distribute public education materials and/or sponsor an information booth at HDCA events. Such initiatives would provide the opportunity for knowledgeable volunteers to discuss water conservation and protection measures with residents on a one-on-one basis and solicit feedback on the effectiveness of the public education programs.

As discussed in Section 3.0, education and technical assistance programs could be developed to provide assistance to owners of properties where businesses and hobby farms have been identified.

5.0 TASKS 4 AND 5 – GROUNDWATER MONITORING PROGRAM

A groundwater monitoring program was implemented under Phase 2 of the Study for the purposes of:

- Collecting water-level data in select monitoring wells to monitor seasonal and long-term changes in the groundwater flow regime and to verify and refine the numerical modeling results; and,

- Collecting groundwater quality samples for analysis of general potability parameters, including total metals, anions, physical parameters and bacteriological constituents (total coliform and *E. coli*), to establish baseline groundwater chemistry conditions.

The results of the water balance analyses (Phase 1) and the contaminant inventory (Phase 2, Task 1) were reviewed and recommendations were developed for further refinement of the groundwater monitoring program during Phase 3 of the Study.

5.1 Water-Level and Groundwater Quality Monitoring

5.1.1 Methodology

The groundwater monitoring program was implemented in a phased approach. Under Phase 1 of the Study, three (3) unused wells were proposed as monitoring wells (Golder, 2008). Access to two of the proposed monitoring wells was obtained by the Highlands and the groundwater monitoring program commenced at monitoring wells DOH-01 and DOH-02A on January 23, 2009. The locations of monitoring wells DOH-01 and DOH-02A are presented on Figure 4.

Golder retained the services of a qualified water well driller to remove the existing lids from monitoring wells DOH-01 and DOH-02A and equip each well with a welded, lockable lid. Golder deployed electronic data loggers (pressure transducers) in well DOH-01 and DOH-02A; one additional pressure transducer (a "barologger") was deployed in DOH-02A to monitor changes in barometric (*i.e.*, atmospheric) pressure. The pressure transducers were programmed to collect data on a synchronized frequency of every 12 hours. The pressure transducers were subsequently reprogrammed on February 17, 2009 to collect data every three hours. Data were retrieved from the pressure transducers in February, May and September, 2009.

Golder personnel collected groundwater samples from wells DOH-01 and DOH-02A on February 17 and 18, 2009. The wells were purged with a submersible pump that was operated at maximum capacity. Flow rates ranged from approximately 18 litres per minute [L/min; 4.8 US gallons per minute (USgpm)] to 8 Lpm (2.1 USgpm); the capacity of the pump diminished as water-levels in the pumped well decreased. Over three (3) well volumes were purged from well DOH-02A. Due to the depth of well DOH-01 (*i.e.*, approximately 500 feet; 152 m) and the response to pumping, approximately 1.1 well volumes were purged from the well after five (5) hours of pumping. Field parameters including pH, temperature, specific conductance and oxidation-reduction potential (ORP), and visual indicators (*i.e.*, turbidity, colour, etc.) were monitored and recorded. Once chemical equilibrium was achieved, samples were collected in laboratory-supplied sampling containers and preserved as required; Golder personnel wore dedicated nitrile gloves during collection of the samples. The samples were packed with ice in coolers and submitted to ALS Laboratory Group, Environmental Division (ALS) of Vancouver, BC for analysis of general potability parameters. ALS has achieved proficiency certification by the Canadian Association for Laboratory Accreditation Inc. (CALA) for the analyses it conducted for this investigation.

Golder reviewed the results of the first water quality monitoring event and, based on the level of effort required to collect the groundwater samples, it was recommended that further groundwater quality sampling be conducted on wells that were equipped with an existing pump. Utilization of wells with existing pumps would eliminate the requirement to deploy a temporary pump to collect samples from unused wells, permitting implementation of the program in a more cost-effective manner.

Groundwater samples were collected from DOH-02A on May 25, 2009 following the sampling protocols discussed above. Groundwater samples were not collected from DOH-01 in May due to the level of effort required to obtain representative samples from the well.

Golder provided technical support to the Highlands in composing the text for an article in the Highlands Community Newsletter. The article requested interested residents to volunteer use of their well for groundwater monitoring. A list of volunteer wells was compiled at the District office and Golder, in collaboration with the Groundwater Task Force, selected candidate wells based on well locations and completion details (*i.e.*, depth). In addition to residential wells, wells located on municipal properties were also selected for inclusion in the monitoring program. It is anticipated that the Highlands will have continued access to these wells in the future, should the wells be designated for long term monitoring.

On September 21 and 29, 2009, Golder personnel met with volunteer well owners at their respective properties and assessed the suitability of their well for the collection of a manual water-level measurement and the suitability of the water distribution system for the collection of a raw water sample prior to treatment and/or a storage tank. Based on the results of the site visits, the groundwater monitoring program was expanded to include wells DOH-03 through DOH-10, commencing with the September 2009 monitoring events (Figure 4). At the times of the site visits, where possible Golder personnel measured and recorded manual water-level measurements and collected groundwater samples. Manual water level measurements were collected from monitoring wells DOH-03, DOH-05, DOH-06, DOH-07, DOH-08, DOH-09A and DOH-10. Continuous water level measurements were also collected from monitoring wells DOH-01 and DOH-02A using pressure transducers. Groundwater quality samples were collected from DOH-02B, DOH-03, DOH-04, DOH-06, DOH-07, DOH-08, DOH-09B and DOH-10. Due to practical considerations, at locations DOH-02 and DOH-09, water-level data and water quality samples were collected from different wells; water-level data were collected at wells labeled as "A" and water quality samples were collected from wells labeled as "B". Water quality samples were collected upon stabilization of field parameters, preserved and submitted to ALS for analysis.

5.1.2 Results

Groundwater Levels

Detailed water-level data collected from monitoring wells DOH-01 and DOH-02A are presented on Figure 5, together with daily total precipitation data from the Victoria Highland Weather Station for the period December 2008 through September 2009.

Water-levels in DOH-01, located in the central portion of the Highlands at an elevation estimated to be approximately 180 metres above sea level (m asl), generally exhibit a distinct pattern of decline and subsequent recovery over short periods of time (*e.g.*, three to five days). These patterns suggest a relatively strong hydraulic connection between DOH-01 and a nearby well that is pumped on a regular basis. Groundwater levels measured prior to decline are inferred to represent static groundwater conditions. Static groundwater-levels generally ranged from depths of approximately 11.2 m below the top of (well) casing (m btoc; 36.8 ft btoc) in late January to approximately 15.0 m btoc (49.2 ft btoc) in mid-July. The magnitude of the pattern of decline and recovery increased from approximately 2 to 3 m (6.5 to 9.8 ft) in February and March to up to approximately 13 m (42.7 ft) in the summer months that are characterized with relatively less precipitation.

Water-levels in DOH-02A were measured to range from depths of approximately 15.2 m btoc (49.9 ft btoc) in March and April to approximately 27.3 m btoc (89.6 ft btoc) in September. The water-levels in DOH-02A were relatively stable over short periods of time and were consistent with seasonal precipitation patterns.

Manual depth to water measurements that were collected during the September 21 and 29, 2009 groundwater monitoring events are presented in Table 4, at the end of this report.

Groundwater Quality

The results of the groundwater quality testing program are presented in Table 4 and copies of the laboratory Certificates of Analyses (COAs) are provided in Appendix IV. The analytical results are generally within the Guidelines for Canadian Drinking Water Quality (GCDWQ) criteria with the following exceptions:

- **Physical tests:** colour in the sample that was collected from DOH-02A during the May 2009 event was reported to be above the AO criteria of 15.0 total colour units (TCU), at a value of 16.0 TCU. Total dissolved solids reported for the sample from DOH-03 was above the aesthetic objective (AO) of 500 mg/L, at a concentration of 969 mg/L. Turbidity ranged from 0.19 NTU to 24.4 NTU in samples from DOH-08 and DOH-02A, respectively

- **Bacteriological tests:** total coliform bacteria reported for samples from DOH-02A, DOH-03, DOH-04, DOH-07, DOH-08 and DOH-09B were greater than the GCDWQ criteria of 0 most probable number[2] (MPN)/100 mL, at reported values ranging from 1/100 mL to greater than 201/100 mL, respectively; and,

- **Total metals:** concentrations of iron reported for samples from DOH-01, DOH-02A, DOH-02B, DOH-03 and DOH-9B at values ranging from 0.65 mg/L to 2.1 mg/L were above the AO of 0.3 mg/L. Concentrations of manganese reported for samples from DOH-01, DOH-02A, DOH-2B and DOH-04 were above the AO of 0.05 mg/L, at concentrations ranging from 0.0522 mg/L to 0.467 mg/L.

The analytical results from the groundwater quality testing program were generally consistent with the analytical results presented in previous hydrogeological reports. The analytical results are considered to be representative of general groundwater quality in the Highlands and characteristic of groundwater in a crystalline bedrock aquifer.

[2] The analytical results for bacteriological analyses are quantified by a statistical estimation of the density of bacteria (most probable number in a representative sample) per volume.

Based on the analytical results, the groundwater in the bedrock aquifer is mineralized and relatively hard. Major ions in the groundwater samples are bicarbonate, chloride, sulphate, calcium, magnesium, silicon and sodium. Concentrations of iron and manganese that are above the aesthetic objective criteria are common in groundwater samples from similar hydrogeologic settings. Analytical results for total coliform bacteria, a large group of bacteria commonly found in soil and water, provide a general indicator of microbial water quality. The results of the Escherichia coli (*E. coli*) analyses (*i.e.*, <1/100mL) presented in Table 4 suggest that the coliform bacteria detected in certain samples are not specific to fecal sources. Furthermore, it is understood that the water from wells DOH-02A, DOH-03 and DOH-09B (>201/100mL) is not used for drinking water purposes.

Quality Assurance and Quality Control (QA/QC)

A Quality Assurance and Quality Control (QA/QC) program was implemented for the groundwater quality sampling program. Replicate field samples were collected from monitoring well DOH-02B during the September 2009 sampling event. The QA/QC results are presented in Table 5, at the end of this report. The relative percent difference (RPD) between the analytical results reported for the replicate field samples was less than 10%; the RPD calculation was not applied to parameters that were less than five times the lab detection limit.

Each batch of samples analysed and reported by ALS for this Study included at least one laboratory duplicate sample, one analytical blank or one reference sample (a certified reference standard, spike or control standard). The QA/QC data presented in the Quality Control Reports generally complied with the laboratory data quality objectives (DQOs).

Based on a review of the ALS QA/QC data, the laboratory analytical data is considered reproducible and reliable for the assessment of groundwater quality in the Highlands.

5.2 Recommendations

5.2.1 Water-Level Monitoring

Golder reviewed the results of the water balance analysis (Phase 1) to identify monitoring well locations in areas that would provide water-level information required to further refine the numerical model. During Phase 3 of the Study, it is anticipated that continuous water levels will continue to be collected from wells DOH-01 and DOH-02A. Golder recommends installation of pressure transducers in monitoring wells DOH-03, DOH-09A and in an unused well that is located adjacent to DOH-07 to collect continuous

water-level information. Golder also recommends further investigation of the municipal properties near monitoring well DOH-04 (*i.e.*, West Fire Hall and Caleb Pike Heritage Park) to identify an unused well in which a pressure transducer can be deployed. It is further recommended that manual water levels continue to be measure in monitoring wells DOH-05, DOH-06, DOH-07, DOH-08 and DOH-10.

5.2.2 Water Quality Monitoring

It is recommended that groundwater quality monitoring continue at wells DOH-02B, DOH-03, DOH-04, DOH-06, DOH-07, DOH-08, DOH-09B and DOH-10. It is understood that, following the well inspection on September 21, 2009, the water distribution system at DOH-05 has been equipped with a tap to enable collection of a raw water sample. It is anticipated that water quality samples will be collected from well DOH-05 during subsequent monitoring events.

As discussed in Section 2.3, potential contamination from current and historical land uses on C/I properties in the southern portion of the Highlands received the highest priority ranking for the purposes of groundwater protection planning. Potential sources of groundwater contamination at these properties generally include metals, hydrocarbons including LEPH, HEPH, PAHs, VOCs, VPH and BTEX (Table 2.) Glycol contamination may have occurred in the vicinity of an auto wrecking facility and in areas where vehicles and equipment are maintained and dioxins and furans may have been introduced to groundwater at the Highwest Waste Management Facility and the Millstream Meadows property due to burning of wastes and at Millstream Industrial Park in the area of the tire fire.

When potential sources of contamination similar to those presented for the C/I properties are identified, the installation of one or more sentinel wells at strategic locations would typically be recommended to monitor groundwater quality. However, groundwater flow in bedrock aquifer systems is localised within structural discontinuities and fracture systems. As a result, contaminants that are introduced to the aquifer could be transported through fracture networks that are not necessarily intercepted by the sentinel wells. Under these circumstances, it is possible that the groundwater monitoring program would not detect contaminants that are present in the system. Therefore, it is recommended that a groundwater monitoring program be conducted using existing wells to assess groundwater quality in the vicinity of the C/I properties.

As discussed in Section 2.2.2, environmental monitoring and remediation programs have been and/or are currently being implemented at the majority of the C/I properties. Groundwater monitoring events are regularly conducted at the Highwest Waste Management Facility and at the Millstream Meadows property. During a routine

groundwater monitoring event at the Millstream Meadows property in 2007, hydrocarbon contamination was observed in a monitoring well located outside the an area of documented contamination. In response to these results, the CRD undertook measures to test water wells within a 1 km radius of the property for concentrations of LEPH, HEPH and PAHs, and implement a site remediation plan. This sequence of events illustrates the value of monitoring groundwater quality in strategic wells over time.

Golder recommends that the Highlands continue to liaise with the CRD and site operators at C/I properties to identify and discuss opportunities to share information and coordinate groundwater monitoring efforts. Golder further recommends continuation of the quarterly groundwater monitoring program that is currently being conducted by the CRD for wells within a 1 km radius of the Millstream Meadows property and expansion of the program to include analysis for concentrations of VOCs, including BTEX.

6.0 RECOMMENDATIONS

6.1 Preliminary Groundwater Protection Planning

It is recommended that preliminary measures for groundwater protection be implemented to encourage conservation of groundwater quantity and the protection of groundwater quality. Public education initiatives that are supported by market approaches and technical assistance, hazardous waste collection and well abandonment programs would provide a comprehensive approach to addressing potential sources of groundwater contamination that were identified for rural and rural residential properties. Coordination of the public education initiatives with existing programs in the Highlands would support implementation in an efficient and cost-effective manner. It is recommended that public education initiatives be further developed during Phase 3 of the Study.

6.2 Additional Data Requirements

Contaminant Inventory

It is recommended that the Highlands maintain a database of specific land uses and significant accidents on transportation routes and power transmission corridors in the Highlands. Additional information is required to assess the nature of on-site facilities and land use practices on properties where businesses and hobby farms have been identified. It is also recommended that further information regarding land use practices at the Bear Mountain Golf Course be gathered to confirm the priority ranking that has been assigned to land use activities associated with the golf course.

The results of the land use surveys should be documented in a database that also includes details regarding significant accidents, fires or spills that may have occurred in the Highlands. Documentation should be maintained concerning hazardous materials that may have been released to the environment and, if possible, estimated volumes of hazardous materials that were released.

The database would serve to supplement the existing contaminant inventory and provide guidance on reallocation of groundwater protection efforts, as required.

Model Refinement

Additional data were identified during completion of Phase 1 of the Study that would assist with refinement of the numerical model to reduce uncertainty and support an assessment of seasonal variations.

Deployment of pressure transducers in monitoring wells DOH-03, DOH-09A and DOH-07, and in a well near DOH-04 will facilitate collection of detailed water-level information in the southern, eastern, northern and western portions of the Highlands, respectively. These data, in conjunction with the detailed data obtained from monitoring wells DOH-01 and DOH-02A and continuous water-level data that will be available from MoE observation well no. 372, will support refinement of the model and calibration for prediction of transient conditions.

It is recommended that estimates of groundwater consumption be further refined. This can be accomplished with the installation, operation and monitoring of flow meters on specific wells. Candidate wells include the wells that are operated by the Bear Mountain Golf Course and a selection of privately owned domestic wells. Water withdrawals are already currently being monitored from the well that services the River's Crossing development and the Hanington Creek Estates subdivision. The resulting data would provide more representative estimates of groundwater consumption in the Highlands and identify seasonal patterns in consumption.

It is also recommended that the extent of the northwest-trending lineament in the area of the Bear Mountain Golf Course be further investigated to refine the capture zones predicted for the communal/commercial wells (Phase 1) and groundwater flow in the southern portion of the Highlands. This is anticipated to require the installation of a pumping well and/or several observation wells near the currently defined limits of the lineament to facilitate conducting a long-term (72 hr or more) pumping test.

6.3 Water Quality Monitoring

It is recommended that the Highlands engage in discussions with the CRD and site operators at C/I properties to discuss opportunities to share information and coordinate groundwater monitoring efforts. It is recommended that the private water supply wells that are currently sampled on a quarterly basis by the CRD for LEPH, HEPH and PAHs are also analysed for concentrations of VOCs, including BTEX.

6.4 Groundwater Management – Next Steps

Upon finalization of report for Phase 2, it is anticipated that the Highlands will initiate Phase 3 of the Study. As discussed in this report, it is recommended that public education initiatives are further developed during Phase 3 of the Study. Golder proposes to work with the Groundwater Task Force to refine the content of the public education initiatives. Opportunities to coordinate the groundwater protection initiatives with existing programs in the Highlands will be identified to support implementation in an efficient and cost-effective manner.

The objectives of Phase 3 are to continue to implement the groundwater monitoring program and to develop detailed groundwater protection planning initiatives for the Highlands that are consistent with the results of the first two phases of the project. It is anticipated that the detailed protection planning will consist of identifying measures to protect groundwater quality, developing contingency plans for alternate water sources (which specifically would not include piped services in the vast majority of the Highlands as per the OCP, and may include bottled water, surface water sources, rainwater harvesting and/or other sources), emergency response planning, and the protection of groundwater quantity through water conservation planning. At the outset of Phase 3, Golder will meet with the Groundwater Task Force to refine the proposed activities.

7.0 LIMITATIONS AND USE OF REPORT

This report was prepared for the exclusive use of the District of Highlands. In evaluating the requirements of Phase 2 of the Groundwater Protection Study, Golder Associates Ltd. has related in good faith on information provided by sources noted in this report. We accept no responsibility for any deficiency, misstatements or inaccuracy contained in this report as a result of omissions, misstatements or fraudulent acts of others.

The investigation program followed the standard of care expected of professionals undertaking similar work in British Columbia under similar conditions. No warranty expressed or implied is made.

The report is based on data and information collected during the investigation conducted by Golder Associates Ltd.'s personnel and is based solely on the conditions observed at the times of the site reconnaissances described in this report.

The scope of work for this study was intended to provide an overview only and did not include such items as subsurface investigations, contaminated sites assessment, geotechnical assessment, or hydrogeological field studies.

Comments on groundwater quality have been made based on analysis of samples from discrete locations, and therefore, results cannot necessarily be extrapolated to other portions of the Highlands.

If new information is discovered in the future, Golder Associates Ltd. should be requested to re-evaluate the conclusions of this report and to provide amendments as required prior to any reliance upon the information presented herein. The report, which specifically includes all tables and figures, is based on data and information collected during the investigations conducted by Golder Associates Ltd. The report must be read and understood collectively, and can only be relied on in its totality.

Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Golder Associates Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

8.0 CLOSURE

This report presented the results of Phase 2 of the Groundwater Protection Study for the Highlands.

We trust that the information contained in this report meets the Highlands requirements and look forward to your comments.

GOLDER ASSOCIATES LTD.

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