1.0 INTRODUCTION

This report presents the results of the third phase (Phase 3) of a three-phase Groundwater Protection Study (the "Study") conducted by Golder Associates Ltd. (Golder) on behalf of the District of Highlands Local Government (the "District"). The Phase 3 tasks were completed in accordance with the scopes of work outlined in Golder's letters titled "*Revised Scope of Work Proposed for Phase 3 of the Groundwater Protection Study, District of Highlands*", dated January 21, 2010 (Golder Associates, 2010a) and "*Cost Estimate for the Upgrade of Monitoring Wells DOH-03 and DOH-04A and Stream Flow Monitoring, Groundwater Protection Study, District of Highlands*", dated January 22, 2010 (Golder Associates, 2010b).

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 15.0.

1.1 Background and Objectives

The District of Highlands (the "Highlands") is one of 13-member municipalities of the Capital Regional District (CRD), encompassing approximately 37 km^2 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 water system ("Hanington system") that is supplied by a communal well. Groundwater supplies within the Highlands are derived primarily from drilled wells completed in the Wark-Colquitz Aquifer. This bedrock aquifer is identified as Aquifer No. 680 by the BC Ministry of Environment (MoE) and is categorized as class IIB under the BC Aquifer Classification System, indicating moderate demand relative to aquifer productivity and moderate vulnerability of the aquifer to contamination from surface sources (Kreye, et al*.*, 2002). 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 local government (the "District") retained Golder to conduct a Groundwater Protection Study to assess groundwater conditions throughout the Highlands, to provide the District 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 as three 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 and Phase 2 of the Study are presented in Golder's reports titled "*Phase 1: Groundwater Protection Study, District of Highlands*" (Golder File No. 07-1414-0014), dated October 2008 and "*Phase 2: Groundwater Protection Study, District of Highlands*" (Golder Project No. 07-1414-0014-2000), dated December 2009, respectively (Golder Project No. 07-1414-0014). This current report presents the results of Phase 3 of the Study. Phases 1 through 3 of the Study were completed with input and direction from the Highlands Groundwater Task Force, a team comprising a staff member of the District, a member of the Highlands Council and three volunteer residents.

1.2 Scope of Work

The scope of work for Phase 3 of the Study included the following:

Data Collection and Monitoring Programs

- Task 1 – Stream Flow Monitoring: Golder conducted stream flow monitoring during the wet season in 2010 to supplement the results from the stream flow monitoring event that was conducted in September 2007.
- Task 2 – Monitoring Well Upgrades and Installation of Pressure Transducers: Golder deployed four pressure transducers in monitoring wells DOH-03, DOH-04A, DOH-07A and DOH-09A. Prior to installation of the transducers, Golder retained a qualified water well driller to attach lockable lids to wells DOH-07A and DOH-09A. Golder also retained a qualified pump installer to upgrade wells DOH-03 and DOH-04A to be consistent with the guidelines outlined in the BC *Ground Water Protection Regulation* (GWPR), including placement of an adequate surface seal and measures for floodproofing and wellhead protection.
- Task 3 – Monitoring Programs: Golder conducted three water quality monitoring events in March, September and December 2010 to assess seasonal variations in water quality. Detailed water-level monitoring was conducted through to the end of 2011. In addition to the Highlands groundwater monitoring program, Golder obtained precipitation, groundwater level and water consumption data from a number of stakeholder monitoring programs.

Refinement of Numerical Model

- Task 4 – Refinement of Numerical Model: Based on the results of the monitoring programs, Golder refined the numerical hydrogeological model that was developed during Phase 1 of the Study to assess seasonal variations in groundwater-levels and potential impacts associated with future development and climate change.

Detailed Groundwater Protection Planning

- Task 5 – Groundwater Conservation Planning: Golder conducted a review of the Highlands policies and bylaws, groundwater conservation literature and relevant information from other jurisdictions to identify conservation measures that could be implemented through a combination of regulatory mechanisms, non-regulatory mechanisms and market approaches. Opportunities to coordinate the initiatives with existing programs were identified to support implementation in a cost-effective manner.
- Task 6 – Groundwater Quality Protection Planning: In conjunction with Task 5, Highlands policies and bylaws and groundwater protection literature were reviewed to identify measures to prevent contamination of groundwater supplies. Based on the results of the review, Golder identified regulatory mechanisms, non-regulatory mechanisms and market approaches to address potential sources of groundwater contamination that were identified during the contaminant inventory (Phase 2 of the Study).

- Task 7 – Preliminary Contingency Planning: Golder conducted a desktop review of available information to identify potential alternative water supplies that could be used if there were to be a decrease in the available groundwater supply or a decline in groundwater quality in the future.

- Task 8 – Recommendations for Emergency Response Planning: Golder reviewed the District of Highlands Emergency Response Plan and provided recommendations for the District to refine the Plan and develop measures to support timely and coordinated responses to emergency events that could potentially contaminate groundwater supplies in the Highlands.

Reporting and Project Management

- Tasks 9 and 10 – Reporting: The results of Phase 3 of the Study are presented in a report provided to the Groundwater Task Force for review. The report includes recommendations for implementation of the groundwater protection measures identified during Phase 3. Subsequent revisions to the report will reflect comments received from the Groundwater Task Force. Hard copies and electronic copies of the report will be provided to the Highlands. The copies will be provided in the formats requested in the Terms of Reference.

- Task 11 – Meetings: Golder attended progress meetings with the Groundwater Task Force and will provide a presentation at a Committee of the Whole Meeting on an agreed upon date.

PART I: DATA COLLECTION AND MONITORING PROGRAMS

As presented in the Phase 1 report, Golder developed a District-wide numerical hydrogeological model (numerical model) that was calibrated to steady-state conditions (Golder Associates, 2008). The model was used to conduct water balance analyses to assess the sustainability of current and future groundwater withdrawals. Based on the results of Phases 1 and 2 of the Study, Golder recommended that additional data be collected that would support refinement of the numerical model to assess seasonal variations (Golder Associates, 2009). In particular, the following recommendations were made:

- Conduct stream flow monitoring during the wet season to supplement the results from the stream flow monitoring event that was conducted in September 2007;
- Deploy pressure transducers in monitoring wells in the southern, eastern, western and northern portions of the Highlands to assess groundwater conditions across the aquifer; and
- Refine estimates of groundwater consumption for privately-owned domestic wells and production wells in the southern portion of the Highlands, including those operated for the Bear Mountain Golf Course (Bear Mountain) and the Hanington Creek Estates subdivision.

Section 2.0 presents the results of the stream flow monitoring that was conducted during the wet season of 2010. Under Phase 3 of the Study, four monitoring wells were upgraded and equipped with pressure transducers; a summary of these activities is presented in Section 3.0. The Highlands groundwater monitoring program and other stakeholder monitoring programs are discussed in Sections 4.0 and 5.0, respectively. During Phase 3, Golder also conducted a search of water well records maintained on the BC MoE on the on-line Water Resources Atlas (WRA) and updated the project database (Highlands database) that was compiled during Phase 1 of the Study. Details are provided in Section 6.0.

2.0 STREAM FLOW MONITORING

Golder conducted stream flow monitoring during the wet season to supplement the results from the stream flow monitoring event that was conducted at the end of the dry season in September 2007. Prior to conducting the 2010 wet-season monitoring event, Golder conducted a search of Environment Canada's on-line monitoring network. No active hydrometric stations were identified on Millstream Creek or Craigflower Creek.

Golder conducted baseflow monitoring in the Highlands on March 4, 2010 at the ten locations presented on Figure 2. Streamflow monitoring locations DOH1 and DOH5 through DOH8 generally corresponded to locations that were monitored during the September 2007 event. Locations DOH4 and DOH11 through DOH13 were only monitored during the March 2010 event.

The results for the winter stream flow monitoring event are presented in Appendix A. At the time of the monitoring event, stream flow was calculated to range from approximately 0.005 m^3/s (5 L/s) at DOH7, upstream from Pike Lake, to approximately 0.229 m^3/s (229 L/s) at DOH1, located in the southern portion of Millstream Creek. During the September 2007 monitoring event, only DOH1 was reported to be flowing, at a rate of approximately 0.006 m^3/s (6 L/s).

3.0 MONITORING WELL UPGRADES AND PRESSURE TRANSDUCER INSTALLATION

Based on the results of Phase 2 of the Study, Golder recommended that the groundwater monitoring program be expanded to include continuous water level monitoring at locations DOH-03, DOH-04, DOH-07 and DOH-09. At locations DOH-04, DOH-07 and DOH-09, Golder recommended that groundwater quality samples be collected from wells with that were equipped with existing pumps and operated regularly and continuous water level monitoring be conducted for wells that were not regularly used.

Golder retained DA Smithson and Sons, a qualified water well driller, to remove existing lids from monitoring wells DOH-07B and DOH-09A and equip each well with a welded, lockable lid on January 29, 2010. Golder deployed an electronic data loggers (pressure transducers) in each well.

In collaboration with the District and the Groundwater Task Force, Golder identified a monitoring well on a property near DOH-04A that was designated as Institutional in the Highlands OCP (DOH-04B). Although water from wells DOH-03 and DOH-04B was not being consumed, but rather being used for non-potable purposes at the respective properties, Golder recommended that the wells be upgraded to be consistent with the guidelines outlined in the BC *Ground Water Protection Regulation* (GWPR), including placement of an adequate surface seal and measures for floodproofing and wellhead protection. Following consultation with the Water Stewardship Division of the MoE, Golder retained BC Aquifer, a qualified pump installer, to upgrade wells DOH-03 and DOH-04B on April 29, 2010. At each location, Golder directed BC Aquifer to extend the well casing, place a surface seal around the casing of the well, grade the ground surface to convey surface water away from the well and attach a secure, locked well cap to the well casing. On the following day, Golder returned to each well and attached a well identification plate and deployed a pressure transducer. Golder completed Well Alteration Reports documenting the work and submitted the forms to the MoE.

Photographs of the various stages during the well upgrade process for DOH-04B are presented in Appendix B.

4.0 HIGHLANDS GROUNDWATER MONITORING PROGRAM

The Highlands groundwater monitoring program that was initiated under Phase 2 of the Study was continued during Phase 3. The objective of the Highlands groundwater monitoring program was to:

- Collect water-level data to assess seasonal changes in the groundwater flow regime as input to the numerical modeling; and
- Collect groundwater quality samples for analysis of general potability parameter to establish baseline groundwater chemistry conditions.

As discussed in the preceding section, during Phase 3 of the Study Golder designated four new monitoring wells for the collection of continuous water level data. The methods and results from the Highlands groundwater monitoring program are presented in the following sections.

4.1 Groundwater Monitoring Program

4.1.1 Methods

The Highlands groundwater monitoring program consisted of ten monitoring locations DOH-01 through DOH-10. Due to practical considerations, at monitoring locations DOH-02, DOH-04, DOH-07 and DOH-09, water-level data and water quality samples were collected from separate wells. Monitoring wells DOH-02A, DOH-04B, DOH-07B and DOH-09A were unused wells that were not equipped with pumps (i.e., not operated). These wells were designated for water-level monitoring, as the water-levels in these wells represented static groundwater conditions. Water quality samples were collected from monitoring wells DOH-02B, DOH-04A, DOH-07A and DOH-09B, as these wells were equipped with existing pumps and were operated on a regular basis. The locations of the monitoring wells that were included in the Highlands groundwater monitoring program are presented on Figure 2.

Golder collected detailed water-level data from monitoring wells DOH-01, DOH-02A, DOH-03, DOH-04B, DOH-07B and DOH-09A during Phase 3 from the times that the respective wells were established as monitoring wells through to early January 2012. At each well, Golder deployed an electronic data logger (pressure transducer) in the well to monitor changes in water-levels. Golder deployed one additional pressure transducer (a “barologger”) 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 three hours. Data were periodically retrieved from the pressure transducers over the duration of Phase 3 at strategic times to confirm water-levels prior to seasonal changes such as the end of the dry season prior to the onset of the wet season. During a monitoring event on August 11, 2011, Golder noted that the transducers in DOH-01 and DOH-03 had stopped recording on June 7, 2011 and the transducers in DOH-04B, DOH-07B and DOH-09A had stopped on July 5, 2011. As such, water-level data were not retrieved from these wells for the one to two month period prior to August 11. Golder reprogrammed the transducers and checked that each one was recording data prior to re-deploying them in the monitoring wells. On January 9, 2012, Golder conducted the final manual water-level monitoring event for Phase 3 of the Study. Golder downloaded water-level data from the transducers and redeployed them in the monitoring wells to continue collecting data in 2012. In addition to the continuous water-level monitoring, Golder also collected manual groundwater level measurements from monitoring wells DOH-05, DOH-06, DOH-08 and DOH-10 at the times of the groundwater quality monitoring events.

Golder conducted groundwater sampling at monitoring wells DOH-02B, DOH-03, DOH-04A, DOH-05, DOH-06, DOH-07A, DOH-08, DOH-09B and DOH-10 in March, September and December 2010. At each monitoring location, Golder personnel collected groundwater samples from a tap on the distribution system that permitted the collection of a raw sample prior to treatment or a storage tank. Golder sterilised the tap with isopropanol, turned the tap on and monitored field parameters including pH, temperature, specific conductance and oxidation-reduction potential (ORP). Once chemical equilibrium was achieved, samples were collected in laboratory-supplied sampling containers and preserved as required. At locations DOH-04A, DOH-05 and DOH-06 it was not possible to collect samples directly from the tap. At these locations, Golder connected a hose to the tap to convey the water to a location where samples could be transferred into sample bottles. The hose was sterilised with a solution of approximately 10% bleach and deionised water prior to sampling at each location. Golder personnel wore dedicated nitrile gloves during sampling to minimise the potential for cross-contamination between sampling locations. The samples were packed with ice in coolers and submitted to ALS Laboratory Group, Environmental Division (ALS) of Vancouver, BC under chain-of-custody for analysis of general potability parameters. ALS has achieved proficiency certification from the Canadian Association for Laboratory Accreditation Inc. (CALA) for the analyses it conducted for this investigation.

Upon receiving the analytical results for each monitoring event, Golder drafted email correspondence that the District then provided to each of the volunteer well owners to inform them of the analytical results for their respective wells. In addition to the Certificates of Analyses (COAs), as provided by the lab, well owners were also provided with information sheets that are available through the MoE's Water Stewardship Information Series. Depending upon the results for their particular well, well owners were provided with fact sheets regarding iron, manganese and bacteriological parameters in groundwater, well construction requirements of the GWPR and water well disinfection.

Quality Assurance and Quality Control (QA/QC)

Golder implemented Quality Assurance and Quality Control (QA/QC) measures for the groundwater quality monitoring program. One set of duplicate field samples were collected during each monitoring event and submitted to the lab. The relative percent difference ("RPD" - the absolute difference between the two values, divided by the mean) and, for parameters with concentrations less than five times the lab detection limit, the difference factor ("DF" – the absolute difference between the samples) of duplicate analyses were calculated to assess the reproducibility of the analytical data. RPD and DF values generally should not be more than 20% and two times the lab detection limit, respectively. RPD values greater than 20% may reflect variability within the sample or sampling and/or analytical procedure. Values exceeding this requirement were assessed.

During the March 2010 monitoring event, Golder collected an equipment blank from the hose that was used at locations DOH-04, DOH-05 and DOH-06 to confirm the sterilisation procedure between sampling locations. To achieve this, Golder poured laboratory-supplied deionised water through the hose following sterilisation, collected the discharge in sampling bottles and submitted them to the lab for analysis.

In addition to the QA/QC samples that were collected in the field, 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).

4.1.2 Results and Discussion

4.1.2.1 Groundwater Levels

Detailed water-level data for monitoring wells DOH-01, DOH-02A, DOH-03, DOH-04B, DOH-07B and DOH-09A for the period October 1, 2010 through December 31, 2011, together with daily precipitation data from nearby weather stations (see Section 5.1, below) are presented on Figures 3A through 3D. Manual water-level measurements that were collected at the times of the groundwater quality monitoring events are presented in Table 1.

Static water-levels in the Highlands monitoring wells were generally consistent with seasonal precipitation patterns. Water-levels were generally stable during the wet season between November and April, declined during relatively drier months from May to September and increased between September and November in response to the onset of the wet season. The seasonal responses were relatively greater in monitoring wells located at higher elevations, in inferred recharge areas. The difference in water-levels between the wet season and the dry season was approximately 17 m in DOH-02A (Figure 3B), and approximately 9 m in DOH-10[1] (Table 1), located at elevations greater than 220 m above sea level (m asl) and 260 m asl, respectively. As presented on Figures 3A and 3D, seasonal water-level responses observed in inferred discharge areas ranged from approximately 2 m in DOH-03 to 5 m in DOH-09A. The water-levels in DOH-09A, located near Eagles Lake (Figure 2) ranged from a depth of approximately 5 m below ground surface (m bgs) in mid-September 2011 to inferred flowing artesian conditions in mid-December 2010 (Figure 3D).

Water-levels in Highlands monitoring wells also exhibited variable responses to individual storm events and/or pumping. During the wet season, water-levels in monitoring wells DOH-03, DOH-04B and DOH-09A rose by up to a metre or more over periods of three to five days during periods of high precipitation (Figures 3A, 3B and 3D). These patterns suggest relatively strong hydraulic responses of these wells to infiltrating precipitation and/or surface water bodies. In contrast, the less variable water-levels in monitoring wells DOH-01, DOH-02A and DOH-07B were interpreted to be indicative of general recharge to the bulk bedrock aquifer (Figures 3A, 3B and 3C). Although DOH-01 is located less than 10 m south of an ephemeral stream that was observed to be flowing during precipitation events, the static water-levels in this well were consistently greater than 10 m bgs. This suggests a relatively weak hydraulic connection between the well and flowing water at ground surface.

Monitoring wells DOH-03 and DOH-04B are equipped with pumps and operated as supply wells for non-potable uses (i.e., not for drinking water). The isolated instances when the water-level in DOH-03 declined and subsequently recovered over short periods of less than one day are inferred to reflect times when the well was pumped (Figure 3A). The water-levels in DOH-04B were relatively stable and did not exhibit a strong response to pumping (Figure 3B). Although monitoring well DOH-01 is not equipped with a pump, the water-levels in this well also exhibited a distinct pattern of decline and subsequent recovery over periods of three to five days, suggesting a relatively strong hydraulic connection between DOH-01 and a nearby well that is pumped on a regular basis (Figure 3A).

[1] Inferred static water levels are based on manual measurements that may have been influenced by pumping. Detailed water level monitoring would be required to confirm these results.

4.1.2.2 Groundwater Quality

The field and analytical results for the groundwater quality monitoring that was conducted over the duration of the Study are presented in attached Table 1 and copies of the laboratory Certificates of Analysis (COAs) are provided in Appendix C. The results from the monitoring that was conducted during Phase 3 of the Study are discussed below.

The analytical results for the March, September and December 2010 events were generally within the Health Canada (2010) Guidelines for Canadian Drinking Water Quality (GCDWQ) criteria for the parameters analysed, with the following exceptions:

- The temperature of the well water from monitoring well DOH-08 was measured in the field to be higher than the GCDWQ aesthetic objective (AO) criteria of 15 ºC, at a value of 20.4 ºC (discussed further below).
- The pH of one or more samples from DOH-02B, DOH-03, DOH-05, DOH-07A, DOH-09B and DOH-10 were measured in the field to be lower than the GCDWQ AO criteria range of 6.5 – 8.5.
- The total dissolved solids (TDS) of the samples from DOH-03 were relatively high, with a concentration of 500 mg/L reported for the samples from the Sept 2010 event. The GCDWQ AO criteria for TDS is 500 mg/L.
- The turbidity of samples from monitoring wells DOH-02B, DOH-03, DOH-04A, DOH-05, DOH-06 and DOH-09B were reported to be greater than the turbidity operational guideline (OG) criteria of 1.0 Nephelometric Turbidity Units (NTUs) for one or more groundwater quality monitoring events. Wells DOH-03 and DOH-09B are not used for drinking water purposes.
- For at least one monitoring event in 2010, samples from DOH-03, DOH-04A, DOH-05, DOH-06, DOH-08 and DOH-10 were reported to contain coliform bacteria at concentrations greater than the GCDWQ health-based Maximum Allowable Concentration (MAC) criteria of zero per 100 mL. The samples that were collected from monitoring well DOH-10 in September were also reported to contain Escherichia coli (*E. coli*) at a concentration of 3 per 100 mL. The GCDWQ health-based criteria for *E. coli* is also 0 per 100 mL.
- Concentrations of iron were reported to be higher than the GCDWQ AO criteria of 0.3 mg/L for samples from DOH-02B, DOH-04A, DOH-05 and DOH-09B for one or more monitoring events.
- Samples from DOH-02B, DOH-04A, DOH-05 and DOH-09B were reported to contain concentrations of manganese that were higher than the GCDWQ AO criteria of 0.05 mg/L. It should be noted that the Canadian Drinking Water Quality (2010) guideline for manganese of 0.05 mg/L was established based solely on aesthetic considerations and other documents present guideline values in drinking water that have been developed for the protection of human health.[2].

As discussed in Section 4.1.1, following each monitoring event, well owners were provided with the analytical results for their respective wells. Based on the results from the respective wells, specific courses of action were taken for monitoring wells DOH-10 and DOH-08, as discussed below.

[2] World Health Organization (2009), BC Contaminated Sites Regulation (May 31, 2011)

Immediately following analysis, ALS phoned Golder on September 30, 2010 to advise that detectable concentrations of *E. Coli* were reported for the samples that were collected from DOH-10 on September 28. Golder notified the District immediately and provided assistance to contact the well owner, advise them of the results and recommend the following course of action:

- Golder arranged to re-sample the well at a time that was convenient for the well owner (October 4);
- The well owner was provided with information sheets and agreed to disinfect the well, following collection of the samples on October 4; and
- The well owner boiled potable water until the well was disinfected.

After Golder re-sampled DOH-10 on October 4, the well owner indicated that they would disinfect the well and declined an offer to have Golder collect confirmatory samples following disinfection. As presented on Table 1, no detectable concentrations of *E. coli* were reported for the October 4 samples and total coliform bacteria had declined to 21 per 100 mL from the value of 261 per 100 mL that was reported for the September 28 samples.

Prior to the December 2010 monitoring event, monitoring well DOH-08 was completed with the well casing that extended slightly below grade and was not secured with a sealed cap. The well owner was provided with MoE information sheets outlining construction requirements of the GWPR. At the time of the September 2010 sampling event, the temperature of samples from DOH-08 were measured in the field to be relatively high (20.4 ºC) and the well owner indicated that the pressure in their water system had declined. Golder also recommended that the well owner contact a qualified pump installer to inspect the pump and to upgrade the wellhead conditions. At the time of the December 2010 event, Golder observed that the pipe from the pump had been replaced. Although well casing did not extend the minimum 12-inch stick-up above ground surface, as required under the GWPR, the well was secured with a bolted lid.

Quality Assurance and Quality Control (QA/QC)

The results from the duplicate analyses and the equipment blank sample are presented in attached Tables 2 and 3, respectively. The RPD of the total coliform bacteria analyses for the duplicate samples that were collected from DOH-08 on September 28, 2010 was calculated to be 92%. As discussed in Section 4.1.1, at each sampling location Golder sterilised the tap and, at locations where sampled could not be collected directly from the tap, the hose that was used for sampling. The analytical results for the equipment blank report total coliform bacteria results of less than the lab detection limit of one per 100 mL, suggesting that the sterilisation procedure was effective and the sampling methods did not introduce bacteriological contamination to samples (Table 3). Concentrations of coliform bacteria in samples from DOH-08 were variable over the course of the groundwater monitoring program, ranging from <1 per 100 mL to 1990 per 100 mL. The RPD value of 92% may reflect variability in the number of colloids entrained in the samples. The RPD and DF values for other parameters and sets of duplicate samples were calculated to be within the criteria of 20% and two times the lab detection limit, respectively.

The QA/QC data presented in the ALS Quality Control Reports generally complied with the laboratory data quality objectives.

Based on a review of the QA/QC data presented on Tables 2 and 3 and in the Quality Control Reports, the data from the Highlands groundwater monitoring program are considered reproducible and reliable for the assessment of groundwater quality in the Highlands.

Summary

The results from the Highlands groundwater quality monitoring program are generally consistent with analytical results presented in previous hydrogeological reports and are considered to be characteristic of groundwater in crystalline bedrock aquifers. The groundwater in the bedrock aquifer is mineralised and relatively hard. Major ions in the groundwater samples were bicarbonate, chloride, sulphate, calcium, magnesium, silicon and sodium. Iron and manganese at concentrations that are above the GCDWQ AO criteria are common in bedrock aquifers.

Total coliform bacteria are a large group of bacteria commonly found in soil and surface water. Analytical results for total coliform bacteria provide a general indicator of microbial water quality. The detectable concentrations of coliform bacteria reported for samples from most of the wells in the monitoring program may reflect inadequate wellhead protection (i.e., disturbed, insufficient or absent surface seal) and/or limited natural filtration of infiltrating water as it flows through fractures in the bedrock. Furthermore, the wells were completed as open boreholes that were not constructed with a well screen and filter pack. Elevated turbidity values are also consistent with limited filtration of infiltrating precipitation; however, the data from the water quality monitoring program do not exhibit a strong correlation between total coliform bacteria and turbidity. The occurrence of *E. Coli* is inferred to reflect fecal contamination from surface sources or an improperly functioning septic system.

Data from a longer monitoring period would be required to conduct a detailed assessment of seasonal patterns to groundwater quality; however, the relatively higher concentrations of total coliform bacteria reported for the fall and early winter monitoring events may suggest mobilisation of materials (i.e., organic materials, colloids and dissolved solids) from the ground surface during the onset of the wet season.

The results from the Highlands groundwater monitoring program demonstrate the importance of regular water quality sampling for a privately owned well to confirm the potability of the water and identify changes to water quality that may require further investigation (e.g., inspection and repair of the pump or wellhead conditions, septic system maintenance, etc.).

5.0 STAKEHOLDER MONITORING PROGRAMS

In addition to the Highlands groundwater monitoring program, Golder obtained data from a number of stakeholder monitoring programs that were conducted in the Highlands and relevant to the current Study. The data that were collected from the various monitoring programs are discussed in the following sections.

5.1 Precipitation Monitoring Programs

Golder downloaded available on-line precipitation data from the University of Victoria (2012) School-Based Weather Station Network and Environment Canada's (2012) National Climate Data and Information Archive to assess precipitation patterns in the Highlands.

Figures 3A through 3D present daily precipitation data for the period October 1, 2010 through December 31, 2011 for the following four UVic weather Stations: the District of Highlands Office, located in the southern portion of the Highlands, the West Highlands District Firehall, Calle Revelle Nature Sanctuary, located in the northern portion of the Highlands, and the East Highlands District Firehall (Figure 2). Daily precipitation data for the same period for Environment Canada's Highland Weather Station (Climate ID 1018616), located in the central portion of the Highlands, are presented on Figure 4.

The data reported for the weather stations suggest that precipitation patterns were generally consistent across the Highlands; however, some data were missing for the West Highlands District Firehall and East Highlands District Firehall weather stations. Precipitation was generally highest from October 2010 through January 2011 and October 2010 through December 2011, with precipitation rates greater than 30 mm/day recorded for most stations during these periods. Precipitation was generally declined from February through May and isolated storm precipitation events were observed between June and mid-September.

5.2 BC Ministry of Environment Observation Well Network

Golder downloaded water-level data available on-line from the MoE for Observation Well No. 372 (MoE, 2012), located in the western portion of the Highlands (Figure 2). Water-level data for the period October 1, 2010 through October 31, 2011 are presented on Figure 4 with daily precipitation data for Environment Canada's Highland Weather Station. Water-levels in Well No. 372 generally exhibited a similar seasonal pattern to those observed in Highlands monitoring wells DOH-02A and DOH-04B (Figure 3B). Water levels increased approximately 6 m between October and November 2010 and stayed relatively stable during the wet season before declining steadily from April through the end of October 2011. The data indicate that the water-level in Well No. 372 declined by over 4 m on December 1, 2010 and subsequently recovered to inferred static conditions; however, no explanation was provided on the database. This pattern may reflect pumping in the observation well, as the water-level in this well typically did not exhibit a strong response to individual precipitation events.

5.3 Bear Mountain Monitoring Program

Bear Mountain provided the District with monitoring data that were collected for production wells 407 and 411 and observation wells 413 and 414. The locations of these wells are presented on Figure 2. Golder understands that in July 2011, Bear Mountain installed flow meters to measure flow rates and volumes pumped from production wells 407 and 411 and equipped each well with a pressure transducer to measure water-levels. Seasonal pumping was reported to have commenced on June 3 and stopped on September 20, 2011. The water-level data, as reported by Thurber Engineering Ltd., for wells 407 and 411 are presented in Appendix D (Thurber, 2012). During pumping, drawdown was estimated to be approximately 50 m in well 407 and 90 m in 411. By the end of September, the water-levels in wells 407 and 411 were estimated to have been drawn down by approximately 50 m and 90 m, respectively, in response to pumping. The water-levels subsequently recovered to inferred static conditions following September 20 when the pumps were shut off.

The total volumes pumped from each well were reported from August 11 through to the end of pumping. Based on the aggregate volumes recorded on an approximate weekly basis, production well 407 was estimated to have been pumped at flow rates ranging from approximately 415 m^3/day to 603 m^3/day and well 411 was pumped at flow rates of 693 m^3/day to 1,065 m^3/day. The average flow rates for wells 407 and 411 were calculated to be 556 m^3/day and 858 m^3/day, respectively.

Bear Mountain deployed pressure transducers in observation wells 413 and 414 and has collected detailed water-level data for these wells since October 2008. Water-level data for these observation wells are presented in Appendix D. Water-levels in wells 413 and 414 fluctuated by approximately 4 m and 3 m, respectively, between the dry season and wet season. The wells did not exhibit strong responses to precipitation events or pumping from production wells 407 and 411.

5.4 Hanington Creek Estates Water System

Hanington Creek Estates Water Utility Management provided the District with production data for the Hanington Creek Estates Water System (Hanington System). Well 409 (Well Tag No. 85183) is operated as the primary water supply for the Hanington System and Well 500 (Well Tag No. 85184) is operated periodically as a backup supply. Each well is equipped with a flow meter and a pressure transducer is deployed in Well 500 to collect detailed water-level data. Each residential water service connection in Hanington Creek Estates is metered and water conservation is encouraged through a two-tiered water rate system. A flat rate is applied on a monthly basis throughout the year and, in July, August and September, a surcharge is imposed on residential connections that use more than 50 m^3/month (approximately 1.61 m^3/day).

The Hanington System currently supplies 50 private residences including 48 single family homes and one duplex. Total average weekly water use for the Hanington System was estimated to be approximately 291 m^3/week during the winter of 2011 (January to April) and approximately 694 m^3/week during the summer of 2011 (May to September). These data provided the technical basis to estimate residential groundwater use in the Highlands during the summer and the winter seasons (Appendix E).

Detailed water-level data for Well 500 were not provided in electronic format; however, Golder was provided with a print-out of the water-level data for Well 500. The data suggest that the water-level draws down by approximately 15 m in response to pumping and the inferred static water-level decreased by approximately 3 m during the dry season in 2010 and 2011.

6.0 HIGHLANDS WELL DATABASE

Golder conducted a search of the MoE WRA on January 20, 2012 and identified 134 well records that had been added within the area of the Highlands since the Highlands database was compiled in Phase 1 of the Study. Ten of the new entries provided additional information for wells that were already in the Highlands database. Of the remaining 124 new entries, fourteen records were for wells that had been drilled since 2007. The locations of the water wells in the Highlands database, including the 655 wells that were compiled during Phase 1 of the Study and 123 new locations identified in January 2012, are presented on Figure 5. Accurate locations were not provided for 11 wells that were reported to have been drilled in 2002 in the area of Bear Mountain Golf Course. Also, the record for one new well did not provide coordinates and, as such, this well is not presented on Figure 5.

PART II: NUMERICAL MODELING

As part of the Phase 1 of the Study, a numerical model of groundwater flow in the Highlands was developed and calibrated. The numerical model was constructed using FEFLOW, a three-dimensional finite numerical code developed by WASY Institute in Germany (Diersch, 2000). The model domain covered an area of approximately 60 km^2, encompassed the entire District of Highlands and extended into adjacent jurisdictions, including the District of Saanich to the east and the Districts of Langford and View Royal to the south.

The numerical model developed for the Highlands was a regional-scale model capable of assessing average annual groundwater conditions over large areas. The model was calibrated to static hydraulic head date contained within the water well database, water levels recorded in specific wells during pumping tests and the stream flow measurements recorded by Golder in September 2007 (dry season flows). The model was used to conduct water balance analyses and to assess the influence of future development and the potential impacts of climate change. At the time of model development, seasonal data were not available for model calibration and, therefore, the model was not considered cable of assessing transient (i.e., seasonal) conditions. It was recommended that the model be considered as a “working tool”, which could be refined to simulate transient conditions when seasonal water-level data were to become available.

Following development of the numerical model in Phase 1 of the Study, additional data were collected during Phases 2 and 3 to support refinement of the model for seasonal simulations. These data included wet-season stream flow monitoring data and continuous water-level data from monitoring wells located across the Highlands, as presented in Sections 2.0 and Sections 4.0 and 5.0, respectively. The objective of the modelling exercise during Phase 3 of the Study was to update the numerical model that was developed during Phase 1 to simulate the seasonal variability observed in the monitoring data. The updated model was then used to refine the predicted groundwater water balance for the District and the potential impacts associated with future development and climate change, considering the potential variation of wet season and dry season conditions. The results from the numerical model formed the basis for the development of the conservation and groundwater protection measures presented in Part III of this report.

7.0 REFINEMENT OF NUMERICAL MODEL

7.1 Groundwater Consumption

During Phase 1 of the Study, average residential groundwater consumption was estimated using water use statistics provided by Environment Canada and the CRD. The estimates of 450 L/capita/day (L/c/d) for residents in primary residences and 314 L/c/d for residents in secondary suites did not account for seasonal patterns. Based on discussions with operators of the golf course, total groundwater pumping from two Bear Mountain wells was estimated to have been 1,226 m^3/day. Groundwater use estimates for other large volume users were also estimated based on correspondence with the respective users.

For Phase 3, metered flow data were used to refine groundwater consumption estimates for both the dry season and wet season. As discussed in Section 5.4, groundwater use for the Hanington Creek Estates Subdivision was estimated using operational records provided by the operator of the water system. Private wells on Rural and Rural Residential properties in the Highlands are typically not equipped with flow meters and water use is not measured or reported. Therefore, Golder also used data from the Hanington Creek Estates Water System to estimate per capita groundwater use during the summer and winter months for private residences in the Highlands that are outside the Hanington Creek Estates Subdivision. The calculated values are presented in Table E-2, Appendix E. In general, winter groundwater use was estimated to be 265 L/c/d. Groundwater use was estimated to increase during the summer to 631 L/c/d and 450 L/c/d for residents in primary and secondary suites, respectively. These results were compared to published data for the Greater Victoria Drinking Water System (the “Municipal System”) and found to be greater than, but generally consistent with, average residential water use estimated by the CRD (2009). As such, the calculated values are considered to be conservative estimates of residential groundwater use in the Highlands and were used for the numerical model.

Flow data were also obtained for the wells that are operated by the Bear Mountain Golf Course (Section 5.3). During the summer of 2011, groundwater was estimated to have been pumped from production wells 407 and 411 in August and September at average flow rates of approximately 556 m^3/day and 858 m^3/day, respectively; however, the actual flow rates varied during this period.

Golder also contacted operators in the southern portion of the Highlands to refine estimates of groundwater use for other large volume users. The results are presented in Table E-1, Appendix E.

7.2 Land Use

Land use information, including updated cadastral map information and the results of the 2011 census, was provided by the District. The population of the Highlands was estimated to have increased from 1,903 residents in 2006 to a total of 2,293 in 2011, with 157 people residing in the Hanington Creek Estates Subdivision and the remaining 2,136 residents living on properties designated for Rural or Rural Residential land use. The number of lots developed in the Highlands on Rural or Rural Residential properties was estimated to have increased from 674 during Phase 1 of the Study to 700 during Phase 3.

7.3 Model Development

7.3.1 Model Code

As discussed above, the numerical hydrogeologic model that was developed during Phase 1 of the Study was constructed using FEFLOW numerical code. FEFLOW is capable of simulating three-dimensional (3D) groundwater flow in complex geological settings under a variety of boundary conditions and hydrogeological conditions. Unlike other numerical codes, FEFLOW can simulate discrete features of enhanced permeability, such as lineaments or fractured rock zones, using discrete feature elements. FEFLOW is widely used for hydrogeological modelling worldwide and is well recognized by regulators, the research community and professional hydrogeologists.

7.3.2 Finite Element Mesh

The general model layout and extent of the finite element mesh, as developed during Phase 1, are presented on Figures 6 and 7. Horizontally, the model domain covers an area of approximately 60 km^2 and extends from 459250 m E to 5376100 m E and from 5368050 m N to 5378050 m N. The model encompasses the entire District of Highlands, and extends into the adjacent jurisdictions, including the District of Saanich to the east and the Districts of Langford and View Royal to the south. Vertically, the top of the model is set to ground surface, which ranges in elevation from 0 m above sea level (m asl) near Finlayson Arm to over 440 m asl near Mount Work. The base of the model is horizontal and set to an elevation of 400 m below sea level. Based on estimated hydraulic conductivity data and the installation depth of water wells within the District, it is assumed that groundwater flow at depths greater than 400 m below sea level has a negligible influence on the portion of bedrock utilized by the District for water supply.

The finite element mesh consists of over 140,000 triangular elements. In the horizontal direction, the average size of the element varies from approximately 25 m near major lineaments and pumping well locations, to approximately 75 m along the perimeter of the model domain. Vertically, the model is divided into three layers. The upper two layers are each 150 m thick and the bottom (third) layer ranges from 100 to 550 m thick. Both the horizontal and vertical element sizes were selected to adequately simulate groundwater flow in the bedrock aquifer.

Table 4 presents the initial values of hydrogeological parameters used in the groundwater flow model. These parameters are the values assigned to the numerical model at the end of model calibration in Phase 1 (Golder 2008). Initial values of hydraulic conductivity were assigned in Phase 1 based on well yields and transmissivity values contained in reviewed reports and based on well yields reported in MoE water well records. The hydraulic conductivity values that resulted in the best calibration of the model during Phase 1 are presented on Figure 8. Other values of hydrogeological parameters (ratio of vertical to horizontal hydraulic conductivity, specific storage and specific yield) for which field measurements were not available were assigned based on values published in the literature. During model calibration, some model parameters, including hydraulic conductivity and storage properties were adjusted to improve the match between model predictions and calibration targets. Specific storage is the amount of water an aquifer will release, per unit volume of aquifer, per unit change in hydraulic head, while remaining fully saturated. Specific yield represents the volume of water an aquifer would release, per unit decline in the water table, per unit area of the aquifer (i.e., pore drainage).

7.3.3 Boundary Conditions

Boundary conditions are an important component of the groundwater model because they provide a link between the groundwater system within the area of interest and other components of the hydrologic cycle. Three types of boundary conditions were used in the numerical model, as shown on Figure 9. These included specified head boundaries, specified flux boundaries, and no-flow (zero flux) boundaries.

In general, boundary conditions were not changed relative to the Phase 1 of the Study, except where seasonal data were available and updated estimates of water consumption were available. Of the boundaries assigned to the model only those boundaries that represented recharge from precipitation and withdrawal and recharge from anthropogenic sources were modified relative to those assigned during Phase 1 of the Study.

A specified head boundary is a boundary that assigns a specific hydraulic head to a node in the model. The model permits water to exit or enter the model domain at this node without any limitations in order to maintain the assigned hydraulic head. A specified flux boundary describes a node or element in the model that is assigned a specific flux, such as an aerial recharge rate or pumping rate. The model will remove or introduce the assigned flux at the node or element during the model simulations. A no-flow (zero-flux) boundary is a special case of the specified flux boundary. These boundaries are assigned to nodes or elements across which the flux is set to zero. No-flow boundaries are commonly set along groundwater flow divides or contacts between hydrostratigraphic units that have large differences in permeability (e.g., a high permeability gravel unit abutting low permeability clay unit).

A specified head boundary was used to represent the Finlayson Arm on the western boundary of the model. This boundary was set equal to ground surface, which was approximately zero meters elevation. In addition to Finlayson Arm, specified head boundaries were also used to represent the lakes, wetlands, streams and drainage courses within the model domain. These boundaries were set equal to ground surface along each surface water feature. For wetlands, streams and drainage courses that were inferred to be intermittent, the specified head boundary was constrained to only permit water to leave the model domain (i.e., discharge only). For permanent water bodies, both inflow (recharge) and outflow (discharge) of groundwater was permitted. The assumption that intermittent water bodies do not act as a source of groundwater recharge is considered to be conservative in terms of the objectives of the Study (i.e., it conservatively assumes less available groundwater recharge and therefore less available groundwater for water supply).

No-flow (zero flux) boundaries were used to simulate inferred groundwater flow divides along the perimeter of the model. These boundaries were assigned in all model layers based on the assumption that groundwater divides correspond to topographic divides. A no-flow boundary was also assigned at the base of the model under the assumption that groundwater flow at greater depth has a negligible influence on the portion of bedrock utilized by the District for water supply.

A specified flux boundary was used to simulate aerially distributed recharge from precipitation and human sources. The specified flux was varied based on average wet season (October through April) and average dry season (May through September) precipitation rates. For the model input, long-term climate data were obtained during Phase 1 from the on-line Environment Canada National Climate Archive. Although local data was available from the University of Victoria, the data record is short (October 2010 to present) and not currently suitable for assessing long term average rainfall for the District. Average monthly precipitation data (rainfall and snowfall) were available for the Victoria Highlands weather station for the period 1963 to 2007. The average wet season (October through April) precipitation for this period was 983 mm. The average dry season (May through

September) precipitation for this period was 160 mm. This boundary was applied to the top of the model domain. Infiltration from precipitation was initially assumed to be approximately 8.5% of the average seasonal precipitation based on the results of the Phase 1 model calibration.

In addition to recharge from precipitation, groundwater can be recharged by anthropogenic sources. Because the Highlands is not connected to a municipal sewer system, water from private septic fields contributes to groundwater recharge. Published rates of return indicate about 60% to 85% of per capita consumption of water becomes wastewater with the lower percentages applicable to semiarid regions of the southwestern United States (Tchobanoglous and Burton, 1991). For most the Highlands, it was assumed that 70% of most residential groundwater withdrawals would recharge the aquifer system via septic water return. Wastewater from the Hanington Creek Estates Subdivision discharges to the CRD municipal system. As such, no groundwater recharge was assigned for the Hanington Creek Estates subdivision. Of the communal/commercial users, 70% of the water consumption at, Millstream Industrial Park was assumed to recharge the aquifer as septic water return. At the Bear Mountain Golf Course, it was initially conservatively assumed that groundwater withdrawals matched irrigation requirements and that no aquifer recharge from over irrigation occurred; however, during model calibration a recharge rate of approximately 10% was applied in the area of the golf course, representative of over irrigation, to attain a closer match to observed water levels in this area. All Fun Recreation Centre was identified by Westshore Environmental to be connected to the Langford sewer system. Therefore, groundwater recharge from wastewater produced by the All Fun Recreation Center was not estimated for this property.

A specified flux boundary was used to simulate groundwater use by minor users (i.e., residential water consumption). This boundary was applied to the top of the model over each of the 700 developed lots identified in the Highlands on properties designated for Rural or Rural Residential land use, under the assumption that minor groundwater withdrawals will generally occur within the first layer of the model (within 150 m of ground surface). Major groundwater users were simulated using specified flux boundaries assigned to element nodes representing the location of the well screen. With the exception of two Bear Mountain wells, the flux values assigned to these boundaries were varied according to the average wet and dry season water usage estimates (Appendix E). At Bear Mountain wells 407 and 411, additional pumping rate data were available (Appendix E) and the average pumping rate was varied during simulated operation to more closely match groundwater levels in this area. The pumping rate at well 411 was set at 740 m^3/day from June 2 to August 16 and at 1,090 m^3/day from August 17 until September 20, when the pump was shut down at the end of the irrigation season. The pumping rate at well 407 was set at 650 m^3/day from June 2 to September 8 and at 460 m^3/day from September 9 until September 20.

7.3.4 Discrete Feature Elements

The majority of permeable lineaments in the District of Highlands that were indentified during Phase 1 of the Study were simulated using two-dimensional discrete elements. Discrete feature elements are finite elements of lower dimension that can be inserted at faces and node connections of an existing mesh to represent high permeability connections at scales smaller than the mesh spacing. These elements were arbitrarily assumed to extend to depths of 150 m and have a width of 10 m, with a hydraulic conductivity of 5×10^{-7} m/s.

In the area of Bear Mountain, where pumping test data were available, discrete feature elements were not used to represent the lineaments in that area. In this area, the lineaments were assumed to be up to 40 m in width with initial hydraulic conductivity ranging from 5×10^{-7} to 8.5×10^{-6} m/s and were simulated by adjusting the hydraulic conductivity of the three-dimensional elements along the trend of the lineament. This method was adopted as it provided more accurate simulation of water level drawdown along the lineament in response to transient pumping test data as used in the Phase 1 model calibration.

7.3.5 Model Calibration

Calibration Targets

As part of this Study the model was calibrated to data collected during Phases 1, 2 and 3 of the Study. Data collected during Phase 1 of the Study and used in the model calibration included:

- Static water contained within the water well datable. These included water levels recorded by drillers at the time of well installation, water levels reported at start of pumping tests, and water levels measured during a door-to-door survey that was conducted in June and July 2004. Water levels were reviewed prior to being incorporated in the calibration to eliminate data that were likely erroneous.
- Water levels recorded at pumping and observation wells during eight pumping tests. These pumping tests were selected for calibration purposes in Phase 1 because the wells were located near two communal/commercial groundwater users (Bear Mountain Golf Course and Rivers Crossing). The data collected were used to refine the inferred lineament/fracture network in this area.
- Stream flow measurements recorded by Golder during September 2007. These measurements were collected at the end of the dry season and provide an approximate estimate of the contribution of groundwater discharge to these streams.

Data collected during Phases 2 and 3 of the Study and used in the model calibration included:

- Additional static water levels recorded by drillers at the time of well installation. Water levels were reviewed prior to being incorporated in the calibration to eliminate data that were likely erroneous.
- Continuous groundwater elevation data available for 11 wells located throughout the Highlands.
- Stream flow measurements recorded by Golder in March 2010. The March 2010 measurements were made several days of little to no precipitation; however, surface water likely still contributed a significant volume of the stream flows at that time. These flow measurements are considered an upper bound for the wet season contribution of groundwater discharge to these streams.

Calibration Results

Calibration of the groundwater model involved iterative adjustment of the model input parameters until there was a reasonable match between the simulated and measured hydraulic heads and stream flows. With the exception of the pumping test calibration simulations, the model was run under alternating wet season and dry season conditions until quasi-steady state conditions were achieved. For the pumping test simulations, shorter transient simulations were prepared to represent the duration of the pumping tests (approximately three days). During model calibration, some model parameters, including hydraulic conductivity of the lineaments and storage properties of the bulk bedrock and lineaments, were adjusted to improve the match between model predictions and calibration targets. The model parameters that resulted in best calibration are presented in Table 5 and shown on Figure 10.

During calibration, the specific yield of the major lineaments in the area of Bear Mountain was increased from the estimated initial value of 0.001 to improve the match between model predicted water levels and water levels recorded during the short-term pumping tests and the long term response to pumping at Wells 407 and 411. The specific yield of the two major southerly lineaments in this area was increased to 0.02 and the specific yield of the major northerly lineament was increased to 0.01. This increase in the specific yield of the major lineaments is considered reasonable given likely higher degree of fracturing associated with higher hydraulic conductivity inferred for these elements relative to the surrounding bedrock.

In addition to the adjustments to specific yield, the hydraulic conductivity of the most southerly lineament was increased by two times to 1.5×10^{-5} m/s to improve the match between model-predicted water levels and water levels recorded during the short-term pumping tests and the long-term response to pumping at Wells 407 and 411.

An additional lineament with inferred hydraulic conductivity of 5×10^{-7} m/s was added to the model in the area of Millstream Road and Hanington Road, trending in a northwest southeast direction. This additional lineament was added to improve the match between the measured and predicted drawdown during a pumping test at Well 403. Lineament mapping for the area supports the potential presence of this feature (Journeay, 2008).

Figure 10 presents a graph of model-predicted annual average hydraulic head versus measured hydraulic head at the water wells across the Highlands. The normalized root mean square error between model predictions and field observations, calculated for the calibration points, is approximately 5% for water levels contained in the Highlands well database. Figure 11 presents a graph of model-predicted declines in hydraulic head versus measured declines in head at observation wells for the eight pumping tests. Both calibration results are considered reasonable considering the regional nature of the model area and the Study objectives.

Figures 12A through 12F present the magnitudes of predicted seasonal variations of hydraulic heads versus observed hydraulic heads at wells where continuous water level data were available. In general, the magnitude change of the predicted hydraulic heads corresponded well with the observed water level data. The groundwater model predicted a larger season variation in water level at Well 413, by approximately 10 m, than observed in 2009 and 2010. This variation is likely due to uncertainty in the extent and hydraulic properties of the lineament in this area. This well is located to the northwest of Bear Mountain golf course in an undeveloped area. If this location is identified in the future as an important area for development, further field investigation and small scale refinement of the groundwater model would be required.

Table 6 presents a comparison of model-predicted base flow to measured stream flow. Wet season base flow predictions ranged from 15% to 40% of measured discharge at the ten stream locations visited in March, 2010. This is considered a reasonable match based on the interpretation that the stream flow measurements constitute an upper bound for the groundwater discharge. Dry season base flow prediction for the one location measured in September, 2007 was approximately three times greater than the measured stream flow. This discrepancy is considered reasonable and is likely related to the sensitivity of the measurements to low flow conditions observed at the time of the field investigation.

Overall, the model is considered to be calibrated to observed conditions considering the degree of uncertainty in the hydrogeological data set. Therefore, the calibrated model is considered capable of predicting the water balance for the Highlands with a reasonable degree of accuracy.

8.0 WATER BALANCE ANALYSES

Future development and the impacts of climate change could potentially affect groundwater conditions in the Highlands. In consideration of these factors, a water balance analyse was conducted to assess the sustainability of current and future groundwater withdrawals and the potential impacts of climate change on the water balance for the District Highlands. In addition, an assessment was conducted to identify potential changes in water level elevations that could occur as a result of future development and climate change.

8.1 Factors Potentially Affecting Groundwater Conditions in the Future

8.1.1 Build-Out

Groundwater use was estimated for current development and at the full build-out estimates that were provided by the District. Based on correspondence with the District, full-build out is anticipated to comprise 1,030 developed lots; however, with consideration of current rezoning applications, full build-out could increase to 1,045. A summary of the current and future groundwater use estimates are presented in Tables E-1 through E-3 in Appendix E.

For the purposes of the numerical model, future development was applied to developed properties designated for rural land use, as these properties are generally larger and would more likely be subdivided than rural residential properties.

8.1.2 Climate Change

It is anticipated that precipitation and temperature patterns on southern Vancouver Island will change in the future in response to global climate change. Global Climate Models (GCMs) have been developed to predict future conditions under different scenarios and to assess the uncertainties associated with the various scenarios; however, GMCs typically operate at resolutions that are too coarse of resolution to assess local-scale impacts (Werner, 2011). Although tools such as statistical downscaling can be used to translate the results from GCMs to the local-scale, application of these tools requires detailed assessment and analysis.

The Regional Analysis Tool that is provided by the Pacific Climate Impacts Consortium (2012) uses more than 15 GMCs to estimate future climate conditions for the Pacific and Yukon Regions under a variety of emission scenarios provided by the Intergovernmental Panel on Climate Change (IPCC). Golder used this tool to assess predicted changes to monthly precipitation patterns for the CRD for the 2050’s (2040-2069). Golder reviewed a sample of the data generated by the various models. Although significant variability was observed in the data, the data generally predicted that precipitation would decline during June through September and increase during the winter months for most scenarios. The results from the models also predicted that mean monthly temperatures would increase by values that ranged from less than 1ºC to greater than 4ºC. Detailed statistical analysis would be required to estimate median precipitation and temperature values from the data generated with the Regional Analysis Tool.

For the purposes of the numerical modeling, Golder considered the results from the Regional Analysis Tool and the approach that was developed in consultation with the Groundwater Task Force during Phase 1 of the Study. Although there is relatively high uncertainty regarding the potential impacts of climate change, longer summer drought conditions are generally anticipated for southern Vancouver Island. It is anticipated that this would result in a decrease in groundwater recharge through less precipitation and increased evapotranspiration. The drought conditions may also potentially influence groundwater demand if property owners require more water for irrigation. To simulate the potential impacts of climate change, the rate of recharge from precipitation during the dry season was decreased by 20% and the duration of the dry season was increased by 15 days (half a month). Although total precipitation and intensities of storm events are predicted to increase during the winter months, infiltration into the bedrock aquifer is controlled by the bedrock properties. Therefore, the increased precipitation during the wet season is anticipated to result in more surface runoff rather than increased infiltration. As such, the recharge rate during the wet season was not increased. In the absence of detailed metering data, potential increases in groundwater demand during drier summers were not factored into the consumption estimates that are presented in Table E-3. Appendix E.

8.2 Water Balance Scenarios

Transient model simulations were conducted to determine the water balance under current conditions and four future build-out scenarios. Model predictions are considered representative of average wet season (October to April) and dry season (May to September) conditions and do not reflect shorter-term (i.e., daily or monthly) variations during the year. A description of the water balance scenarios and associated assumptions is provided below.

8.2.1 Current Conditions

For the transient simulation performed for current conditions (the "Base Case"), the model utilized the average wet season and dry season values of recharge and water use that were determined during model calibration.

8.2.2 Future Conditions

Four scenarios were considered for future build-out conditions. With the exception of the changes to the population living in primary and secondary residences, as presented below, the predictive simulations utilized the average wet and dry season values of recharge and water use that were determined during model calibration.

Scenario 1 – Future build-out with 20% secondary suites

In Scenario 1, the number of primary residences using groundwater is assumed to increase from 750 residences to 895. The number of secondary suites is assumed to be 20% of the primary residences (in contrast to the 12% that was estimated under current conditions). The number of residents living in primary and secondary residences are estimated to be 2,405 and 251, respectively, for a total population of 2,656.

Relative to current conditions, changes were made to the communal/commercial water users according to information provided by the respective users. These changes included expansion of the Hanington Creek Estates Subdivision from the 50 residences currently developed to a final build-out of 60 primary residences and connection of the Millstream Industrial Park to the CRD municipal system. The effects of these changes on estimated water consumption are provided in Table 7.

Scenario 2 – Future build-out with 50% secondary suites

In Scenario 2, the number of primary residences using groundwater is assumed to increase from 750 residences to 895. The ratio of secondary suites in primary residences is assumed to increase from 20% to 50%. The total population of 3,032 residents includes 2,405 people living in primary suites and 627 people living in secondary suites. Increased water use at Hanington Estates Subdivision was assumed based on 19 additional secondary suites. The remainder of the major users are identical to Scenario 1.

Scenario 3 – Future build-out with climate change and 20% secondary suites

Conditions for Scenario 3 are identical to Scenario 1 except for the incorporation of the potential impacts of climate change. As discussed in Section 8.1.2, the average dry season precipitation was decreased by 20% and the duration of the dry season was increased by 15 days to simulate the potential impacts of climate change.

Scenario 4 – Future build-out with climate change and 50% secondary suites

Conditions for Scenario 4 are identical to Scenario 2 except for the incorporation of climate change. As in Scenario 3, the potential effects of climate change were simulated by decreasing the average dry season precipitation by 20% and the duration of the dry season was increased by 15 days.

8.3 Water Balance Results

The results of the water balance analyses for the Highlands bedrock aquifer are presented on Table 7. In this table, the water balance has been summarized with respect to major sources of groundwater inflow and outflow to illustrate the relative contributions of precipitation, surface water, and anthropogenic water use to groundwater flow within the bedrock aquifer for the wet season and for the dry season.

In the wet season, the water balance analysis indicates that under current conditions (Base Case), precipitation is the primary source of groundwater recharge (91%), with smaller contributions from surface water (3%), anthropogenic sources (3%), and groundwater inflow from adjacent jurisdictions (3%). Of the groundwater outflow, approximately 69% discharges to surface water bodies in the Highlands, including local creeks, wetlands, lakes and drainage courses, and 17% discharges to Finlayson Arm. An estimated 10% of groundwater is naturally discharged to neighbouring jurisdictions. Groundwater withdrawals from major and minor (residential) water users comprise less than 1% and 4% of the groundwater outflow, respectively.

In the dry season, the water balance analysis indicates that under current conditions, while the precipitation is greatly decreased, it remains the primary source of groundwater recharge (57%). Increased contributions from anthropogenic sources (21%), recharge from surface water (13%) and groundwater inflow from adjacent jurisdictions (7%) were calculated for the dry season. Of the groundwater outflow, approximately 51% discharges to surface water bodies in the Highlands, including local creeks, wetlands, lakes and drainage courses, and 16% discharges to Finlayson Arm. An estimated 9% of groundwater is naturally discharged to neighbouring jurisdictions. Groundwater withdrawals from major and minor water users increase to 13% and 11% of the groundwater outflow, respectively.

Under future build-out conditions and assuming no climate change (Scenarios 1 and 2), the groundwater balance is not expected to change significantly. In the wet season, groundwater consumption by major and minor water users is expected to increase slightly to 1% and 5% to 6%, respectively, and during the dry season groundwater consumption by minor users is expected to increase to 13% to 14%, and consumption by major users would remain at approximately 13%. The volume of groundwater discharging to surface water is predicted to decrease by approximately 2% to 3% for both the wet and dry seasons. Overall, comparison of Scenario 1 results to Scenario 2 results indicates the number of secondary suites (i.e., 20% versus 50% of the primary residences) does not significantly affect the results.

Under future build-out conditions and assuming climate change effects represented by a longer dry season with decreased dry season precipitation (Scenarios 3 and 4), the total groundwater inflow to the Highlands during the dry season is expected to decrease by approximately 5%. Under these conditions, groundwater consumption in the dry season by major and minor water users would constitute 14% and 15% to 16% of the groundwater outflow, respectively. In addition, the volume of groundwater discharging to surface water would be expected to decrease by approximately 8% to 9% during the wet and dry seasons. Groundwater discharge generally maintains a portion of the base flow of creeks, so it can be expected that stream levels could somewhat decline under these scenarios.

8.4 Overall Uncertainty Associated with Water Balance Predictions

The water balance analyses results presented in Table 4 are considered to represent the most likely estimate of groundwater inflow based on the calibrated model (referred to below as the base case scenario); however, as input parameters to the model are subject to some uncertainty, the actual groundwater inflow could be slightly higher or lower than predicted in the base case. Therefore, an assessment of the relative uncertainty in the water balance analyses resulting from the uncertainty in model input parameters was performed.

During the calibration conducted during both Phase 1 and Phase 3 of the Study, the estimated hydraulic conductivity of the bedrock was considered to be the most sensitive parameter affecting model results. Thus, the uncertainty in model predictions was evaluated using the groundwater model with the values of hydraulic conductivity of all bedrock units adjusted by a factor of +/- 2 from the calibrated values. This uncertainty factor was determined by running the model repeatedly with different values of hydraulic conductivity and determining the required precipitation recharge rate required to maintain model calibration (the match between model-predicted and measured data). For a hydraulic conductivity increase by a factor of two, it was necessary to increase the rate of groundwater recharge from precipitation by approximately 15% of the annual precipitation. For a hydraulic conductivity decrease by a factor of two, the rate of groundwater recharge from precipitation had to be decreased to approximately 3% of the annual precipitation. These rates of precipitation were considered to be at the outer limits of what is reasonable for local conditions.

During the sensitivity analysis, no changes were made to the hydraulic conductivity of the lineaments. If the hydraulic conductivity of the lineaments was adjusted, it was found that the predicted declines in water levels did not match the observed water level changes for the eight pumping tests used in the calibration.

Results of the sensitivity analysis are summarized on Table 5 and are presented in Figure 13. Results of the sensitivity simulations indicate groundwater inflow in the wet season could be approximately 80% higher or 60% lower than what was predicted for the base case as result of the assigned recharge. Groundwater inflow in the dry season could be approximately 60% higher or 40% lower than predicted for the base case as result of the assigned recharge.

Groundwater discharge to surface water represents the largest outflow component of the water balance. Groundwater discharge to surface water in the wet season could be approximately 90% higher or 70% lower than the one predicted for the base case. Groundwater discharge to surface water in the dry season could be approximately 70% higher or 60% lower than predicted for the Base Case. These limits represent the reasonable upper and lower bound estimates of the total groundwater inflow / outflow in the Highlands given the range of uncertainty in the model input parameters.

The estimated uncertainty in the predicted groundwater inflow indicates that the relative impact of water supply consumption in the Highlands could be greater than predicted for the base case if the hydraulic conductivity and recharge are inferred to be lower. Groundwater use in the Highlands was predicted to comprise approximately 13% (wet season) to 46% (dry season) of the total groundwater outflow in the lower bound estimate, as compared to lower proportions predicted for the base case (4% to 25%) and upper bound case (2% to 15%).

8.5 Changes in Groundwater Levels Associated with Future Scenarios

Predicted groundwater elevations at the end of the wet and dry seasons for the future scenarios were compared to the predicted water levels for the current conditions.

Full Build-Out

Simulation results for the full-build out scenario indicate that the simulated growth (full build-out) will not have a significant influence on the groundwater elevations in the Highlands. In general, few to no widespread differences to groundwater elevations were observed under Scenarios 1 and 2. At the end of the wet season, groundwater elevations were predicted to be consistent with current conditions, with a decline of approximately one metre observed at upper elevations in the western portion of the Highlands. At the end of the dry season, the decline to groundwater levels in the upper elevations of the western portion of the Highlands was predicted to be approximately 1 to 2 m compared to the Base Case. Localized (i.e., small area) changes were also observed in the southwestern portion of the Highlands in the vicinity of the major groundwater users. Additional data would be required to refine the predicted impacts of water demand by major users in the immediate vicinities of the respective wells.

As discussed in Section 8.1.1, for simulations of future development, increased groundwater demand was distributed evenly across properties within the Highlands that are designated for rural land use. If the future development were to be more spatially concentrated, it is possible that impacts to stream base flow and water levels within the areas of future development could be more significant than what was predicted by the model.

Future Build-Out with Potential Impacts of Climate Change

The model simulations for future conditions suggested that the potential impacts of climate change could have a significant impact on average groundwater conditions within the Highlands. In Scenarios 3 and 4, the effects of climate change resulted in a general decrease in groundwater levels in the Highlands, particularly during the dry season. In general, recharge areas at higher elevations experienced the largest decrease in predicted groundwater levels. Under Scenario 4, representing the largest difference due to full build-out and climate change, at the end of the wet season, groundwater elevations were consistent with current conditions across much of the Highlands; however, decreases of 1 to 3 m were predicted for higher land surface elevations along the western and northern portion of the Highlands. At the end of the dry season, groundwater elevations decreased on the order of 5 to 10 m in areas of higher ground surface elevation, with localized decreases of up to 20 m along the western and central portions of the Highlands when compared to current conditions. Less influence to water levels was observed in groundwater discharge areas at lower elevations.

8.6 Summary

The hydrogeological model developed in Phase 1 was updated and calibrated to data collected in Phases 1, 2 and 3 of the Study. The model was used to assess seasonal variations in the water balance, and impacts of future development and climate change on groundwater conditions. Results of the water balance analysis provides a basis for the Highlands to address some concerns related to maintaining sustainable groundwater withdrawals

The water balance indicated that current groundwater withdrawals for water supply in the Highlands represent a small component of the overall water balance. In addition, the analysis indicated that the simulated growth (full build-out) will not have a significant effect on the current average groundwater conditions within the Highlands in both the wet and dry seasons.

Simulations of future development assumed that increased residential build-out would be spread evenly across the rural residential properties in the Highlands. If future development were to be more spatially concentrated, it is possible that impacts to stream base flow and water levels within the area of the development could be more significant. In addition, impacts to water levels and stream flows could be more significant if a centralized municipal sewer system were installed in the Highlands because groundwater recharge from anthropogenic sources would be reduced.

Simulations for future conditions indicate that the potential impacts of climate change could impact groundwater conditions within the Highlands, particularly during the dry season. For the full build-out scenario with climate change, the predicted groundwater elevations decreased relative to current conditions on the order of 5 to 10 m in areas of higher ground surface elevation, with localized decreases of up to 20 m, along the western and central portions of the Highlands at the end of the dry season. Although the results of this Study indicate, climate change has a large impact on groundwater conditions than simulated full build-out conditions, water conservation programs could help offset the potential impacts of climate change in the Highlands.

PART III: GROUNDWATER PROTECTION PLANNING

As a community that is dependent upon groundwater for its potable water supply, the Highlands realizes the importance of addressing current and potential threats to both groundwater availability and groundwater quality. If measures are not taken to conserve and protect groundwater resources, the economic, social and environmental consequences of inaction can be significant. Declining water levels could potentially result in a loss of water supply, generate conflicts between water users and/or require significant financial resources to secure alternate water supply sources. A decline in groundwater levels could also influence baseflow to surface water sources during the dry season and affect fish and other aquatic habitat.

In addition to the challenges posed by decreasing groundwater levels, groundwater contamination has the potential to affect human health and the environment. The public health implications from consuming contaminated groundwater can be severe, resulting in both acute and chronic effects. These effects can include gastro-intestinal illnesses due to microbiological pathogens and toxic effects from ingestion of heavy metals and hydrocarbons. Contaminated groundwater that discharges into surface water bodies could alter the suitability of the aquatic habitat for fish and other species, interfere with spawning and reproduction, or result in mortality of certain species. The economic impacts of groundwater contamination can be significant and typically include the costs required to implement emergency response measures, secure alternate sources of water supply and conduct environmental investigations required to characterize and, if possible, remediate the contamination.

The goal of the groundwater protection planning exercise was to develop conservation and protection measures that can be implemented by the District to preserve the quantity and quality of groundwater resources in the Highlands. The groundwater protection measures presented in the following sections build upon the results of the numerical model, contaminant inventory and groundwater monitoring program. The groundwater protection measures were developed with consideration of the legislative framework in BC and a water governance model that is most applicable to the Highlands. In particular, opportunities were identified to encourage collaboration and cooperation between stakeholders to implement tools that are available from other local governments and provincial agencies and applicable to the local context.

The results of the groundwater protection planning exercise are presented in Sections 9.0 through 13.0. Section 9.0 presents a summary of the regulatory setting in B.C. and provides a discussion of the governance management framework that is most applicable to the Highlands. Measures for groundwater conservation and protection are presented in Sections 10.0 and 11.0, respectively. Although these topics are discussed in separate sections, groundwater quantity and quality are interconnected and conservation and protection measures should be implemented in a coordinated manner. Sections 12.0 and 13.0 present considerations for contingency and emergency response planning measures that could be implemented in the event that there is a disruption to groundwater supply or quality in the future.

9.0 LEGISLATIVE FRAMEWORK AND GOVERNANCE

Management and governance are key elements to the protection and sustainable use of water resources. "Water management" refers to the operational activities to regulate water and impose conditions on its use, whereas "water governance" refers to the decision-making process through which interests are articulated, input is absorbed, and decisions are made and implemented (Nowlan and Bakker, 2007).

Consideration of the legislative framework and water governance is required to develop groundwater protection measures that can be coordinated with existing programs and implemented in an efficient and cost-effective manner. The existing federal, provincial and municipal legislative framework is discussed in Section 9.1 and proposed new provincial legislation is discussed in Sections 9.2. Section 9.3 outlines how governance has been administered in BC and governance options that will support the implementation of groundwater protection measures that are appropriate for the Highlands.

9.1 Existing Legislative Framework

Although the federal and provincial governments share jurisdiction over water, the Province is primarily responsible for overall management of water resources (Brandes and Curran, 2009). Local governments exercise influence over groundwater use through land use planning and the selection and operation of community water supply systems.

Current federal, provincial and local government legislation related to groundwater is summarised in the following sections. The information presented is intended to provide an overview of the existing legislation, as it relates to groundwater management.

9.1.1 Federal Government

The federal government generally has jurisdiction over water governance related to fisheries, navigation, federal lands and international relations (Environment Canada, 2011). Federal legislation that is most relevant to groundwater resources includes the *Fisheries Act* and the *Canadian Environmental Protection Act*. These laws address the protection of base flows to support protection of fish habitat and the protection of groundwater quality, respectively. Under the *Constitution Act*, the provinces are recognized as "owners" of the water resources and have responsibilities to manage these resources. As such, the federal government rarely plays a significant role in groundwater management or regulation except on federal land and where multiple jurisdictions are involved.

9.1.2 Provincial Government

The provincial government has the primary responsibility for the management of water resources; however, there is no comprehensive set of laws or regulations that fully addresses all aspects of water. Rather, the Province manages water resources through a number of legislative and regulatory mechanisms.

In BC, Government asserts ownership of water and partially regulates the use of water through various pieces of legislation such as the *Water Act* and the *Drinking Water Protection Act*. Licensing, diversion and use of water are currently only applied to surface water. Although the Ground Water Protection Regulation (GWPR) addresses groundwater protection through well construction and closure requirements, no laws exist to regulate either the rates or volumes of groundwater extraction or the resulting impacts, with the exception of the *Environmental Assessment Act* that requires an assessment of new wells which would extract groundwater at rates of more than 75 litres per second (L/s). As a result, there are no systems in place to assess the cumulative impacts of individual wells that are operated within an aquifer or geographic area. As discussed in Section 9.2, the Province is in the process of modernizing the *Water Act* to improve management of this important resource.

The *Drinking Water Protection Act* and Drinking Water Protection Regulation are administered by the Ministry of Health (MoH) through the Local Health Authorities. The Act and regulation require water supply systems to supply potable water and are intended to provide a framework for the protection of the province's drinking water from "source-to-tap"; however, the Act regulates water supply systems and does not apply to domestic water systems that serve one single-family residence. As such, the majority of the privately owned water systems operated in the Highlands are not under the jurisdiction of the Vancouver Island Health Authority (VIHA).

A summary of the water-related legislation in BC is presented in Table F-1, Appendix F.

9.1.3 Local Government

Local governments address water conservation and protection primarily through land use management tools/instruments. Pursuant to the *Local Government Act*, local governments establish an Official Community Plan (OCP) and supporting bylaws that guide decisions about land use, zoning and development. Zoning strategies can reduce potential groundwater contamination by prohibiting certain land uses and municipal bylaws can be effective tools to encourage water conservation. Local governments are also authorised to designate Development Permit Areas (DPAs) for implementation of more stringent development controls to support groundwater protection and conservation.

Local governments can regulate water efficiency through the BC Building Code. The Building Code is a regulation of the *Local Government Act* that outlines water efficiency standards for the construction, alteration or renovation of buildings. Local governments also have some authority to regulate the storage and application of fertilisers, compost and pesticides.

9.2 Proposed New Legislation

Under the Living Water Smart Plan, the government of BC is currently in the process of modernizing the *Water Act* to change the way that water is governed and managed in the province (Living Water Smart, 2011). The *Water Act* modernization process was launched in 2009 and has involved engagement with a broad group of stakeholders. Golder provided technical assistance to the District in developing a formal response that was submitted to the MoE in the May, 2010.

Following review and analysis of the public input, the MoE developed a draft proposal for a new *Water Sustainability Act* that would replace the existing *Water Act* (MoE, 2010). It is anticipated that the *Water Sustainability Act* will include provisions for economic incentives and instruments to improve water efficiency and conservation, collaboration mechanisms to share information and resources, and opportunities to enable a range of government approaches. The Highlands is well-positioned to respond to the policy directions that are proposed under the *Water Sustainability Act* and to work collaboratively with other organisations to manage groundwater resources across the District.

9.3 Groundwater Governance

Groundwater governance can be described as the collective interactions of four factors:

1) the mechanisms (policies, initiatives, regulations and public engagement) used to protect the water resource,
2) the agencies and institutions responsible for groundwater management, and their roles, responsibilities and working relationships (e.g., management framework),
3) the financial framework used to fund groundwater management, and
4) the mechanisms for data collection, assessment and reporting to support decision making.

There are various water governance management frameworks, as outlined in recent publications by Nowlan and Bakker (2007) and Brandes and Curran (2010). As illustrated by the schematic in Figure 14, below, the frameworks vary based on the degree of government control on decision-making (vertical axis) and the degree of stakeholder involvement (horizontal axis).

In British Columbia, water governance has been administered through an increasingly delegated (i.e., devolved or shared) approach with involvement from both government and non-government organizations. Although a governance model has not been selected for the proposed *Water Sustainability Act*, it is anticipated that the province will move towards a less centralized approach to water management and governance with lower legislative and institutional control. To date, the District has implemented a collaborative approach to water governance with strong input from the local community.

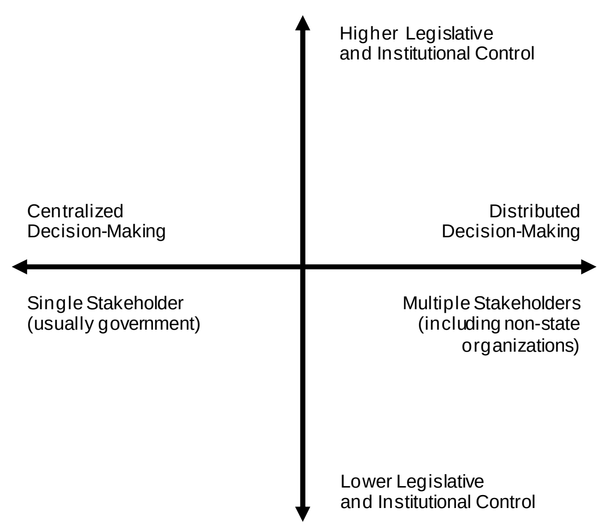

Figure 14: Plot of potential groundwater management frameworks
[Reference: Modified from Brandes and Curran (2010)]

The advantages of collaborative approaches to water governance, as outlined by Nowlan and Bakker (August 2010), may include:

- Access to “local” expertise which can improve the quality of decision-making;
- The ability to adapt regulatory programs to meet local conditions;
- Empowerment of stakeholders (particularly those traditionally marginalized);
- Reinforcement of “social trust” between stakeholders and reduction of conflict over competing uses;
- Greater cooperation in information-sharing;
- Greater political legitimacy (and thus enforceability) of water management planning outcomes; and
- More positive outcomes that have the buy-in and support of influential interests.

Possible disadvantages of collaborative approaches to governance, also outlined by Nowlan and Bakker (August 2010), may include:

- A focus on local environmental interests may exclude regional or national environmental concerns;
- Emphasis on consensus may lead to politically workable solutions, rather than environmentally optimal solutions;
- Unequal representation of stakeholders may develop at the local level;
- Long-term stability may be undermined by large amounts of volunteer time required (i.e., risk of “burnout”); and
- There may be greater overall costs and more time required to produce outcomes such as water use or watershed plans.

In the absence of a comprehensive provincial strategy on groundwater governance, the Highlands is well-suited to continue to pursue a shared, collaborative approach, whereby planning and decision making is undertaken at the local level with stakeholder involvement and support from the provincial government. The Highlands Sustainability Task Force, Water Stewardship Project and Groundwater Task Force initiatives represent both a strong technical basis to support decision-making at the local level and avenues for public involvement. Communication and collaboration with other local governments in BC will provide the Highlands with the opportunity to share information and stay informed on new developments in groundwater protection. Ongoing correspondence between the Highlands and the provincial government will provide an opportunity to adapt regulatory programs to the local conditions and to explore economic incentives that may be available to the Highlands. This governance structure could be reconsidered once the *Water Sustainability Act* is introduced.

The groundwater protection mechanisms presented in the following sections were developed with consideration of the governance approach that has been implemented in the Highlands to provide a groundwater management framework that is applicable and appropriate to the local context.

10.0 GROUNDWATER CONSERVATION PLANNING

The two major factors that could influence future groundwater availability in the Highlands are development and potential impacts associated with climate change. Groundwater demand could increase both through new development (primary residences) and additions to existing residences, including development of secondary suites. Development and land use practices can also change the landscape and influence natural drainage patterns and groundwater recharge.

Potential impacts of climate change could influence groundwater supply in the future. As discussed in Section 8.1.2, climate change is expected to result in longer, drier summers and potentially decreased annual recharge. Under these circumstances, it is expected that available groundwater supply would decline and water demand for irrigation would increase during the hotter, drier summers. The British Columbia Drought Response Plan recognises the importance of local responses to drought management, and emphasizes the importance of collecting information, communicating with the public and implementing water conservation strategies (Econnics, 2010). However, effective water conservation strategies are implemented to reduce water demand over the long term rather than just during drought periods. The US Environmental Protection Agency (1998) provides guidelines for the development of water conservation plans. Although these guidelines are primarily intended for operators of water utilities, a number of the recommended conservation planning measures can be adopted by local governments to encourage conservation at the community level including:

- Information and education;
- Water-use audits;
- Retrofits to existing fixtures or appliances;
- Landscape efficiency;
- Replacement of older fixtures or appliances: and
- Promotion of new technologies, including demonstrations and pilot programs.

In the majority of the Highlands, it is estimated that groundwater is primarily used for domestic purposes (indoor and outdoor use), with some allocation to hobby farms and home-based businesses. The CRD reports that average daily residential water use in the Municipal System service area is 297 litres per person per day (L/p/d) and daily demand doubles during the summer months (CRD, 2009). Although education programs from the District may have encouraged residents to practice water conservation, outdoor water use may be higher in the Highlands compared to other parts of the CRD due to relatively larger lot sizes in the Highlands. In the absence of water metering data, it is not possible to accurately assess groundwater use in the Highlands.

For local governments that operate municipal water supply systems, conservation-oriented water pricing tools can be implemented to influence users' decisions and encourage conservation (Brandes et al., 2010). Because the District is not a water purveyor, it does not have the jurisdiction to implement the operational tools (water metering) and economic tools (rate structures, pricing policies, etc.) required to apply a water pricing strategy. In the absence of water restriction bylaws and/or water rate structures, some well owners may perceive groundwater to be a “free” resource and they may not recognize the importance of water conservation, particularly if their well has a relatively high yield. As such, one of the primary roles for the District in conservation planning is to educate well owners about the benefits of groundwater conservation including:

- Cost savings: reduced energy consumption to operate the pump (and treatment system, pressure tank, etc., if used), decreased and deferred costs of pump maintenance and repair, and reduced costs of chemicals (if used for treatment);
- Decreased competition: less potential competition between neighbours and water uses such as drinking water, irrigation, commercial, etc.;
- Environmental benefits: less water removed from the aquifer and baseflow to surface water bodies is maintained during the dry season; and
- Stewardship: demonstrates leadership the protection and management of natural resources.

The goal of the groundwater conservation planning exercise was to develop the framework for a conservation strategy that the District could implement to encourage conservation and efficient groundwater use and also to enhance groundwater recharge to the bedrock aquifer in order to mitigate potential decreases in future groundwater supply. Golder conducted a review of the Highlands policies and bylaws, groundwater conservation literature and relevant information from other jurisdictions to identify conservation measures that could be implemented through a combination of regulatory mechanisms, non-regulatory mechanisms and market approaches. Complementary initiatives being implemented within the Highlands by the Highlands Sustainability Task Force (HSTF) and by other local governments were also considered to identify opportunities for collaboration.

10.1 Regulatory Mechanisms

In accordance with the *Local Government Act*, the District can support groundwater conservation and protection through a number of regulatory mechanisms. These regulatory mechanisms are generally applied to new development or existing development when an application is received for building permits for subdivision of an existing property of a renovation or alteration to an existing building (including addition of a secondary suite). Given that much of the development within the Highlands has already occurred, the District has limited jurisdiction to manage groundwater demand and minimize impacts to groundwater recharge through regulatory avenues.

Regulatory mechanisms are best implemented when there is consistency between the OCP and the supporting zoning and bylaws and the regulatory framework incorporates aquifer-scale planning that is based on a strong technical framework, such as the results of the numerical model and data from groundwater and surface water monitoring programs. While regulatory mechanisms provide local governments with greater authority to implement groundwater conservation strategies, additional resources and technical expertise are required to set terms of reference and to review information when received from applicants.

As discussed in Section 8.3, the results of the numerical model suggest that groundwater level decline may be greatest in the groundwater recharge areas of the Highlands. As a result, the District could consider placing more emphasis on groundwater recharge areas for the purposes of groundwater conservation.

10.1.1 Official Community Plan (OCP)

The Highlands OCP identifies groundwater as one of the major factors that will determine future land use in the Highlands (District of Highlands, 2007). The OCP highlights the importance of water resources and provides a strong foundation for a bylaw structure that incorporates specific groundwater conservation measures, as discussed in the following sections.

10.1.2 Zoning and Land Use Designations

Zoning Bylaw No. 100 establishes land use designations and outlines applicable regulations for the respective designations (District of Highlands, 2011). The majority of the groundwater recharge areas in the Highlands are designated for park, rural and rural residential land uses. These land uses are inherently consistent with groundwater conservation, as large tracts of natural landscape have been retained and rural and rural residential properties are characterised with relatively large lot sizes and limit density. Bylaw No. 100 could be revised to rezone groundwater recharge areas with a land use designation that includes additional groundwater conservation measures; however, recharge areas could also be addressed with Development Permit Areas (DPAs), as discussed in the following section.

10.1.3 Development Permit Areas (DPAs)

Development Permit Areas have been designated in the Highlands for the protection of natural resources and environmentally sensitive areas (District of Highlands, 2007). The District could designate Aquifer Protection DPAs to limit development (including secondary suites) in groundwater recharge areas. For these DPAs, approval of development permits could be contingent upon specific criteria that could include the following:

- Limits to site disturbance to maintain natural soils and vegetation;
- No net change to pre- and post-development hydrology;
- Limits the total amount of impermeable surfaces on a property and/or requirements for permeable paving and engineered infiltration systems such as infiltration ponds, bioswales, etc. to promote rainwater infiltration;
- Requirements for landscape designs to comply with specified seasonal water budgets;
- Measures for alternative water sources such as rainwater; and
- Requirements for groundwater monitoring.

10.1.4 Bylaws

Bylaw No. 154 establishes standards for work and services for subdivision or development of land (District of Highlands, 2002). The existing standards presented in Schedule B could be refined and/or new bylaws could be developed for the Aquifer Protection DPAs to reinforce groundwater conservation, as discussed below.

Section WA – Standards for Water Service and Fire Protection should be revised to require that wells be constructed in accordance with the BC Ground Water Protection Regulation (GWPR) to support compliance with future well siting and well testing requirements that are anticipated under Phase 2 of the GWPR. It is recommended that a pumping test that is a minimum of 72-hours in duration be required to estimate well yield; however, the results of the pumping test should not be considered to represent the sustainability of the entire aquifer system, but rather the well itself. The cumulative effects of withdrawals from individual wells should be assessed using the results of the numerical model. Section WA should also be cross-referenced with the requirements specified in the Aquifer Protection DPA.

Section D – Standards for Storm Water Management could be revised to create limits on total amount of impermeable surfaces, include requirements to minimize effective impermeability[3] and/or mandate no net change to pre-development infiltration. The standards could also be revised to require use of permeable paving and incorporation of engineered infiltration systems such as infiltration ponds, bioswales and/or subsurface disposal systems to achieve no net increase in post-development storm water flows. Water quality considerations associated with engineered infiltration systems are discussed in Section 11.1.4.

Section R – Standards for Roads should also be revised to reflect changes to the storm water management standards to maintain consistency.

Consideration could also be given to developing new bylaws for landscape and irrigation water conservation standards. These bylaws could include requirements to submit landscape designs that comply with specified landscape water budget targets that are discussed in Section 11.2.2. New bylaws could also be developed for rainwater harvesting, with consideration to the technical details that are presented in Section 11.2.2.

10.2 Non-Regulatory Mechanisms

Public education and outreach programs are required not only to educate well owners about the importance of groundwater conservation, but also to provide them with the tools to assess current water use, evaluate potential groundwater conservation opportunities and implement appropriate measures. The District currently implements a number of groundwater education initiatives through its newsletter, website and correspondence with residents. In addition to these activities, the District may consider developing a conservation strategy that develops and advocates a household audit program and landscape planning and irrigation initiatives to reduce groundwater demand and encourage the use of alternative water supplies for non-potable uses. In particular, rainwater and greywater (i.e., domestic wastewater from washing machines, and kitchen and bathroom drains, but not toilets that contain human waste) can represent a viable water sources for irrigation or toilet flushing;

[3] "Effective impermeability" relates to how much of the total precipitation that falls on a site is infiltrated into the ground, as opposed to "actual impermeability" which refers to the amount of a site that is covered by surfaces through which infiltration is minimal (Okanagan Basin Water Board, 2009).

however, the treatment and management practices that must be implemented to address potential health hazards associated with greywater use may prevent individual residences from adopting greywater reuse systems for domestic purposes.

10.2.1 Household Audit Program – Water Use

The District could consider implementing a program to install flow meters on volunteer residential wells. This would generate data that could assist in the refinement of groundwater demand estimates, provide well owners with an opportunity to assess their water use behaviours and assess the influence of groundwater conservation measures.

In the absence of metering data, it is not possible for residents to accurately measure and monitor their water use. A variety of on-line tools such as the GoBlue One Minute Water Calculator (http://goblue.zerofootprint.net/) and Environment Canada's Water Use Calculator (http://www.on.ec.gc.ca/reseau/watercalculator/) are available to estimate household water use. While these calculators provide a basis for estimating water use, the calculators are somewhat generic and do not account for specific variables such as the types of faucets and appliances in the household, specifics regarding outside areas that are irrigated, seasonal variations or leaks and losses in the system.

In accordance with HSTF Recommendation 20, a household audit program could be developed to provide Highlands residents with a tool that can be used to more accurately estimate domestic water use and assess seasonal patterns in consumption. The household self-audit tool should be accompanied with supporting information that identifies conservation measures such as reducing water use through efficient practices, repairing leaks, and retrofitting older water-using fixtures and appliances with water efficient options such as faucet aerators, low-flush toilets and water efficient appliances. The household audit could also include a calculator that estimates the volumes of water that could be conserved with each of the respective conservation measures to demonstrate the benefits to the home owner.

The household audit could be developed to include both water and energy use, as recommended by the Highlands Sustainability Task Force (District of Highlands, 2009). The self-audit could also be implemented in coordination with the landscape design and irrigation tools discussed in the following section and the groundwater protection aspects discussed in Section 11.2.1.

The household audit program could be developed as a self-audit tool to provide residents with the opportunity to conduct their own audit. Alternatively, the audit program could be conducted by trained representatives (e.g., District staff, students or volunteer residents) and the results could be compiled on a database to establish baseline conditions, guide education campaigns and assess the potential benefits of proposed market approaches. These data would provide the technical basis for the District to assess changes in water use (HSTF Recommendation 14).

10.2.2 Landscape and Irrigation Planning

The CRD (2009) estimates that average daily residential water use in the Municipal System service area doubles during the summer months. The CRD further estimates that approximately 65% of the water used for irrigation is wasted due to inefficient watering practices. Although the District has limited jurisdiction to impose watering restrictions on private well owners, there are non-regulatory tools that can be implemented to support HSTF Recommendation 23 and encourage reductions in outdoor water use through landscape design and improved irrigation efficiency.

Re-landscaping lawn areas that require relatively high irrigation with drought resistant plants can significantly reduce the amount of water used for irrigation during the dry season. The City of Kelowna (2010) presents guidelines for landscape design and irrigation practices that can be implemented to achieve a water conservation target or water budget. With this approach, a landscape water budget is established and the property is divided into high (e.g., lawns and vegetable gardens), medium and low (e.g., xeriscaped and/or planted with native vegetation) water use areas, or “hydrozones”, and non-watered pervious areas to meet the water budget. Irrigation systems are designed to water the hydrozones according to water use requirements. The benefit of this performance-based approach is that it provides general guidelines and enables the land owner to select the design that will achieve the objective. Although this landscaping approach would be voluntary for existing homeowners, the District could consider requiring a water budget approach to landscaping for new development through bylaws.

Outdoor water conservation can also be achieved with use of efficient irrigation technology and through proper operation and maintenance of the system. Automatic irrigation controllers can be programmed for customized schedules that account for seasonal factors, and soil and weather conditions. Non-oscillating irrigation systems with nozzles that apply water evenly can save up to 30% in water usage and drip irrigation systems that apply water only to plant roots are the most efficient irrigation method (City of Kelowna, 2010). Proper operation (e.g., watering times, nozzle orientation, etc.) and maintenance (e.g., cleaning nozzles and pipes) of irrigation systems further improves efficiencies. As part of the Team WaterSmart campaign, the Regional District of Nanaimo (RDN; 2011a) provided free irrigation system inspections for local residents. Trained representatives visited residences, assessed the irrigation system and provided a customized report that identified problem areas and provided suggestions to improve the system.

10.2.3 Rainwater Harvesting

As outlined in HSTF Recommendation 23, rainwater harvesting could be supported in the Highlands to reduce groundwater demand. Rainwater harvesting has been used to reduce groundwater demand in areas on Vancouver Island and the Gulf Islands. Applications range from the use of rain barrels to capture and store precipitation for outdoor irrigation to rainwater harvesting systems (RWH systems) that collect, store and distribute rainwater for a variety of non-potable uses. When compared to rain barrels, RWH systems typically collect relatively large volumes of rainwater that are more likely to offset groundwater demand during the dry summer season. As such, RWH systems include one or more cisterns (i.e., storage reservoirs) that must be sized with consideration to precipitation and climate factors, dwelling size, fixtures and appliances, and indoor and outdoor water use (Stubbs, 2006).

When used both for outdoor irrigation and to supplement indoor use such as toilet flushing, RWH systems can mitigate groundwater use during the spring and early summer. Capture and use of rainwater for toilet flushing enhances groundwater through the septic system. Furthermore, if RWH systems are used regularly for indoor use throughout the year, the storage capacity can mitigate peak runoff during storm events.

RWH systems must comply with the BC Building Code and, depending upon the system design and the application, plumbing, electrical and building permits are required for the respective system components. If rainwater is used for indoor applications, a dual distribution system is required. RWH systems should also comply with District Bylaw requirements related to siting and minimum setbacks. If the RWH system is used as a potable water supply, additional measures are required, including requirements for water treatment that includes filtration and disinfection. Regular system maintenance and water quality monitoring should also be implemented. If the District intends to implement initiatives to support RWH, the Gulf Islands Trust and VIHA may provide input to the lessons learned from other jurisdictions. The City of Guelph (2011) provides a Best Practices manual for the design and installation of residential RWH systems.

10.3 Market Approaches

In addition to education and outreach measures, financial penalties and incentives are often required to encourage individual well owners to engage in groundwater conservation activities. While the District does not have jurisdiction to impose penalties on well owner who use relatively large volumes of water, it can provide incentives to reward well owners who implement groundwater conservation measures. Use of incentives is a particularly important strategy for private well owners who may not perceive a need for conservation activities and may realize relatively lower cost savings compared to homeowners who are serviced by a municipal water supply system. The District could reserve a certain portion of the financial incentives for the Aquifer Protection DPAs to encourage conservation measures in groundwater recharge areas.

Financial incentives that the District may wish to consider include rebates, subsidies, grants and/or funding for demonstration projects. It is recommended that the District prioritize financial incentives based on highest expected benefit for the money invested. As discussed in Section 10.2.2, significant water savings can be realised through landscaping and efficient irrigation. The CRD (2009) estimates that toilets, washing machines and showers account for 27%, 22% and 17% of indoor water use, respectively. As outlined in HSTF Recommendations 13 and 21, the District may wish to consider providing rebates for replacement of older toilets with low-flush models and washing machines with high-efficiency models, and retrofitting showers with low-flow shower heads. Financial incentives could also be offered for the installation and regular monitoring of water meters on privately owned wells to support the groundwater monitoring program.

Consideration should also be given to the magnitude of the financial incentive that would be required to encourage a well owner to invest in relatively expensive measures such as a RWH system. For these initiatives, the District may wish to consider funding a limited number of demonstration projects. The District may wish to pursue sources of funding that may also be available through municipal, provincial and federal initiatives. For example, as discussed in Section 9.2, it is anticipated that economic incentives and instruments will be available under the proposed *Water Sustainability Act* to support water efficiency and conservation. In particular, it is anticipated that funding will be available under the Living Water Smart plan to support funding for household evaluations (Living Water Smart, 2011).

11.0 GROUNDWATER QUALITY PROTECTION PLANNING

In conjunction with the conservation measures discussed in the preceding section, Golder's review of the Highlands policies and bylaws, groundwater protection literature and information from other jurisdictions was also conducted to identify measures to prevent contamination of groundwater supplies. Groundwater quality protection measures are generally developed with consideration to both the nature and distribution of potential hazards and the vulnerability of the aquifer to contamination. The contaminant inventory that was compiled during Phase 2 of the Study identified and ranks potential sources of contamination in the Highlands. The results from a groundwater vulnerability study were reviewed and analysed with consideration of the results of the conceptual model that was developed during Phase 1 of the Study to assess the intrinsic vulnerability of the bedrock aquifer in the Highlands.

The Vancouver Island Water Resources Vulnerability Mapping Project (VMP) compiled a variety of data sources at different scales and employed the DRASTIC method to produce intrinsic groundwater vulnerability maps for regional districts on Vancouver Island (Liggett and Gilchrist, 2010). The results from this project were accessed on-line from GeoBC and are presented on the Figure presented in Appendix G (GeoBC, 2011). The VMP results characterize the majority of the Highlands with low intrinsic vulnerability; however, the DRASTIC method can be somewhat subjective and can underestimate the influence of key variables that may be relatively more important in particular aquifer systems. For example, in bedrock settings such as the Highlands, the characteristics of the bedrock can exert a relatively stronger influence on vulnerability than that assigned with the DRASTIC method. This is because flow of contaminants through fractured bedrock can be variable and relatively fast (Golder Associates, 2010c), particularly through dissolution features that are inferred to present in the vicinity of the limestone/marble deposits that have been reported in areas of the Highlands (Golder Associates, 2008). Furthermore, the VMP assigned a generalized hydraulic conductivity value for the bedrock aquifer that did not account for the lineaments that were identified in previous studies by Journeay (2003) and characterized as discrete feature elements in the numerical model. Although a fractured media (Fm) variable was developed by Denny et al., (2007) for use with the DRASTIC method to assess the influence of fault and fracture systems for similar bedrock units in the Southern Gulf Islands, this variable was not used for the VMP. The depth to groundwater can also cause the vulnerability to be underestimated by the DRASTIC method when applied to a setting like the Highlands because contaminants travel relatively quickly through unsaturated bedrock compared to unconsolidated deposits such as sand or silt.

While the results from the VMP provide a useful screening-level tool that is intended to be used for regional scale applications, more detailed study is recommended to support land use and groundwater protection decisions. The results from the conceptual model that was developed during Phase 1 of the Study indicate that the surficial sediments in the Highlands are generally thin (approximately 2 to 3 m on average) and discontinuous (Golder Associates, 2008). The sediments range from highly permeable colluvium, sand and gravel, to relatively less permeable clay, till and organic soils (Blyth and Rutter, 1993). These deposits are inferred to provide limited protection to the underlying bedrock aquifer. Therefore, it is recommended that the District focus on the nature and distribution of potential sources of contamination to guide efforts to protect groundwater quality.

The regulatory mechanisms, non-regulatory mechanisms and market approaches that are presented in the following sections were developed to address the potential sources of groundwater contamination that were identified during the contaminant inventory.

11.1 Regulatory Mechanisms

As presented in the report for Phase 2 of the Study, a number of environmental investigations and monitoring programs have been conducted on select Commercial/Industrial properties in the southern portion of the Highlands and the MoE maintains a Site Registry that contains information regarding sites that have entered into the site assessment and remediation process (Golder, 2009). In addition to collaborating with stakeholders that are managing their properties under the provincial regulatory process, the District may also wish to consider legislative tools that are available to support groundwater quality protection across the Highlands, as presented in the following sections.

11.1.1 Official Community Plan (OCP)

The OCP currently outlines policies for watershed and groundwater management, prevention of soil and water pollution and the protection of environmentally sensitive areas including water features and riparian areas. The District could consider options to enhance this policy regarding the protection of groundwater quality, in conjunction with the supporting legislative tools discussed below.

11.1.2 Zoning and Land Use Designations

Zoning bylaws could be used to regulate development by prohibiting activities and land uses that could potentially result in groundwater contamination. Based on the results of the contaminant inventory in Phase 2 of the Study, the District could consider amendments to Zoning Bylaw No. 100 to preclude home-based businesses (e.g., automotive repair, service and salvaging, excavation and/or construction, metal recycling, cabinetry and woodworking, etc.) that involve the use, storage and potentially disposal of chemicals and hazardous products, and recreational and agricultural operations that apply chemicals such as fertilisers, pesticides and/or herbicides. Alternatively, specific land uses, including home-based businesses, could be regulated through the use of DPAs, as discussed below.

11.1.3 Development Permit Areas (DPAs)

As discussed in the preceding section, the District could establish DPAs to:

- Regulate land use activities to prevent the potential for specific types of groundwater contamination (e.g., storage and handling of fuels and hazardous substances, application of pesticides and herbicides, etc.);
- Mandate the use of applicable best management practices and standards for commercial and industrial properties;
- Require environmental studies to establish baseline environmental conditions and subsequent monitoring requirements to confirm post-development conditions; and
- Require ongoing inspection and maintenance of septic systems and inspection of fuel tanks based on a permit renewal cycle or at the time of property transactions.

The above measures could be implemented in DPAs to protect groundwater quality, particularly in recharge areas. Also, if the District were to designate DPAs in groundwater recharge areas to enhance rainwater infiltration (see Section 10.1.3) measures should also be implemented to protect the quality of the water that is infiltrating the subsurface (MWALP, 2002). Specific standards could be established in the form of bylaws, as discussed in the following section.

11.1.4 Bylaws

The existing standards in Bylaw No. 154, Schedule B could be refined to include measures to treat storm water to reduce concentrations of pollutants prior to infiltration. If the **Standards for Storm Water Management** (Section D) and **Standards for Roads** (Section R) are revised to require the use of engineered infiltration systems, the construction standards should stipulate material specifications (i.e., grain size, hydraulic conductivity, etc.) and requirements to demonstrate adequate stormwater renovation based on minimum infiltrative thickness, retention times and/or bioretention capacity (i.e., vegetation type).

The District could adopt a bylaw requiring that unused wells be closed in accordance with the specifications set out in the GWPR or, if the well may potentially be used for water supply or groundwater monitoring in the future, upgraded to be compliant with the minimum well construction requirements of the GWPR such as surface sealing, well identification, floodproofing, protection of the wellhead and securing with an adequate well cap. The BC Ministry of Community Development and MoE have established a model well closure bylaw that could be used as a model (Okanagan Water Board, 2009).

A bylaw could also be introduced to require secondary containment measures for fuel storage tanks to mitigate the introduction of fuel into the groundwater from leaky tanks. The District could also consider adopting a bylaw that requires documentation of ongoing inspection and maintenance of septic systems and inspection of fuel tanks at the time of permit issuance and renewal.

11.2 Non-Regulatory Mechanisms

The public education programs that the District currently implements could be supplemented with non-regulatory measures that are designed to address the potential hazards identified in the contaminant inventory. The District could develop a suite of non-regulatory measures that include both initiatives that are developed for the Highlands and linkages to existing tools and sources of information that are available from other jurisdictions and organisations. Application of a combination of new and available tools will facilitate implementation of groundwater quality protection measures that are relevant to the local context in a cost-effective manner.

11.2.1 Household Audit Program – Groundwater Protection

The household audit program that is discussed in Section 10.2.1 could also include measures to assess potential sources of contamination and provide supporting information regarding groundwater protection measures. This would provide the District with the opportunity to reinforce public education programs and help well owners identify specific groundwater protection measures that could be implemented on their properties.

The supporting information could be delivered through the technical assistance programs discussed in the following section.

The results of the household audit program should be entered into the database and reviewed regularly to identify trends and to guide groundwater protection efforts. The results of the audits could also be summarised and conveyed to residents through the Highlander newsletter and other venues to support ongoing public education.

11.2.2 Technical Assistance Programs

11.2.2.1 Commercial/Industrial Properties

In collaboration with site operators at commercial/industrial (C/I) properties and the MoE, the District could assess environmental practices currently used at the C/I properties and, if required, identify best management plans (BMPs) and waste disposal programs that could be implemented to support groundwater protection. For example, the Automotive Recyclers' Environmental Association provides BMPs for vehicle dismantlers that outline activities for work areas, equipment and infrastructure requirements, and emergency and spill procedures (AREA, 2011). As discussed in Section 11.3, the District could consider the use of financial incentives to encourage site operators of C/I properties to adopt and implement BMPs and other environmental practices.

11.2.2.2 Bear Mountain Comprehensive Development

The District is corresponding with the operators of the Bear Mountain Golf Course to support the development and implementation of a BMP for the golf course operations. The District should review the BMP to confirm that measures are in place for activities such as application, storage and disposal of pesticides and other chemicals and that the BMP is consistent with guidelines and BMPs available from the MoE (2011a) and the Integrated Pest Management (IPM) strategies and guidelines available from the BC Ministry of Agriculture (MoA, 2011).

11.2.2.3 Residential Properties

Based on the results of the contaminant inventory, the District could develop technical assistance programs to address the potential sources of contamination that are common to residential properties including:

- Use, storage and disposal of chemicals and hazardous products;
- Wellhead protection (i.e., surface seal, well caps and covers, floodproofing, etc.) and closure of unused wells in accordance with the requirements of the GWPR;
- Inspection, operation and maintenance of septic systems; and
- Inspection of fuel storage tanks and implementation of spill containment and secondary containment measures.

The District could collaborate with other local governments and provincial agencies to develop packages that are based on existing tools and resources that are relevant to the Highlands. For example, the MoE provides information pamphlets and fact sheets for well owners regarding the GWPR and groundwater quality that are available on-line through the Water Stewardship Division (MoE, 2011b). The RDN has implemented "wellSMART" and "SepticSmart" programs to assist residents in protecting the supply and quality of the water from residential wells and operate and maintain residential septic systems, respectively (RDN, 2011a). Through these initiatives, the RDN has developed information brochures and provided residents with tools to maintain records, hosted workshops, implemented education programs and coordinated monitoring programs. These programs emphasize the importance of groundwater protection but also the cost savings associated regular operation and maintenance of water and septic systems.

11.2.2.4 Home-based businesses

The District could develop information packages and BMPs for operators of home-based businesses where on-site facilities have the potential to introduce contamination to the groundwater. These BMPs would be specific to the nature of each business. For example, the BMP that is developed for automotive recycling facilities on the C/I properties could also be applied to similar home-based businesses where similar facilities exist.

11.2.2.5 Hobby Farms

In collaboration with community groups and, potentially, provincial agencies such as the MoA and the BC Agriculture Council, the District could develop an information package for hobby farms in the Highlands. The information package could be based on existing programs that have been developed by rural municipalities such as the Agricultural Stewardship initiatives implemented by the City of Abbottsford, BC (2011) and information provided by the MoA such as Crop Production Guides and Integrated Pest Management (IPM) strategies and guidelines (MoA, 2011). Although the majority of these tools are designed for agricultural producers rather than hobby farmers, these resources could be used as the technical basis to develop tools that are customized for hobby farm in the Highlands.

11.2.3 Household Hazardous Waste Collection

A household hazardous waste collection program involves the collection of hazardous wastes within groundwater protection areas to mitigate potential groundwater contamination due to accidental spills or inappropriate disposal of chemicals or wastes. The Hartland Landfill that is operated by the CRD accepts household hazardous waste from residents free of charge. The District could provide pamphlets to residents as part of the household audit (see Section 11.2.1). The household audit could include a questionnaire to determine whether residents in the Highlands utilize this service and, if not, what the reasons are. If distance traveled and/or convenience are listed as barriers to regular disposal of hazardous wastes at the Hartland Landfill, the District could consider developing a hazardous waste collection program to encourage residents to regularly remove these products from their property for appropriate disposal. In addition to residential users, the District could also consider accepting agricultural chemicals and pesticides from hobby farms and hazardous wastes from operators of C/I properties as part of the collection program.

The hazardous waste collection program could involve establishing 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.

11.3 Market Approaches

It is anticipated that market approaches may be required to encourage residents and business operators in the Highlands to adopt and implement the groundwater quality protection measures discussed above and other innovative measures that protect groundwater quality. In the absence of regulatory requirements, financial incentives such as reduced application fees and/or taxes may be required to encourage developers to implement groundwater protection measures such as engineered infiltration systems and to close wells in accordance with the GWPR.

The District could also consider providing incentives or reduced taxes to operators of C/I properties, the Bear Mountain Golf Course, home-based businesses and hobby farms to implement BMPs and upgrade facilities to reduce the potential for groundwater contamination. As discussed in the preceding section, the District may wish to consider including hobby farms and businesses in a hazardous waste collection program; however, it is anticipated that the District would have to negotiate with the CRD and/or provide funding for this initiative, as hazardous waste disposal at the Hartland Landfill is not currently available for commercial businesses.

The District could also consider providing rebates to encourage residents to upgrade and/or close wells that are not compliant with the requirements of the GWPR, inspect and maintain septic systems and inspect and replace leaking fuel tanks. The District could explore options to organize the services of qualified contractors to provide services to inspect and upgrade wells, septic systems or fuel tanks to home owners for discounted rates.

It is recommended that the District collaborate with other local governments and agencies to assess sources of funding that may be available for initiatives and agencies, identify opportunities to collaborate and potentially share resources.

12.0 PRELIMINARY CONTINGENCY PLANNING

The objective of contingency planning is to identify alternative water supplies that could be used if there were to be a decrease in the available groundwater supply or a decline in groundwater quality in the future. The preliminary contingency planning measures that are discussed in this section are intended to address potential longer term trends such as a decrease in groundwater levels due to potential impacts from climate change or a general deterioration of groundwater quality across large areas of the Highlands. Section 13.0 outlines emergency response planning measures that can be implemented to guide responses to discrete and/or localized events that have the potential to contaminate groundwater supplies.

Golder conducted a desktop review of available information to identify potential alternative water supplies for the Highlands. Information was gathered through a search of the Highlands database that was compiled during Phase 1 of the Study, information available on-line and files maintained by the Highlands and Golder. Provincial and Local Government legislation, as they relate to water management, were also considered. The results are presented in the following sections.

12.1 Roles and Responsibilities

Although the District maintains dry hydrants across the Highlands to provide an adequate water supply for fire fighting, it but does not operate a municipal water supply system. As such, the District does not have responsibility for the provision of adequate supply to residents and other water users. It is the responsibility of the individual private well owners and commercial/communal well operators to monitor well performance and, if required, to identify and secure access to alternative sources of water supply.

The role of the Highlands is to advocate groundwater conservation and protection through regulatory and non-regulatory mechanisms and to provide information to well owners in the event that one or more alternative water supplies are required. The groundwater monitoring program and numerical model represent the technical framework by which the District can monitor long term trends in groundwater conditions at the District level and identify areas in which to focus groundwater conservation efforts.

12.2 Alternative Water Supply Sources

As discussed in Section 8.1.2, potential impacts of climate change may include less precipitation during the summer months and, as a result, longer and drier summers. The seasonal decline observed in groundwater levels in areas of the Highlands may become more pronounced and well yields may decline during the drought conditions; however, it is anticipated that the aquifer would recharge during the wet winter months. In the event that well yields decline during the summer months, alternative water supply sources may only be required to supplement existing wells for a discrete period of one or two months. Furthermore, the bedrock aquifer in the majority of the Highlands is variable. Therefore, if alternative water supply sources were to be necessary in the future, it is anticipated that the alternative sources would be required to supplement wells with relatively lower yields and/or in recharge areas, rather than uniformly across the Highlands.

In the event that contingency measures were to be required due to a decline in groundwater quality for an existing well, it is anticipated that appropriate treatment would be required or an alternative water supply source would be required to replace, rather than supplement, the existing well.

Considerations associated with potential alternative water supply options are discussed in the following sections.

12.2.1 Bulk Water Delivery

Bulk water delivery may be a practical option to supplement the yield from an existing well during the dry, summer season. Bulk water can be scheduled as needed and can be delivered either as bottled water or with tanker trucks, if the water user has a tank with sufficient volume. Other than the tank requirements, use of bulk water generally does not require construction of additional infrastructure.

12.2.2 Groundwater

12.2.2.1 Modification to Existing Wells

If the yield from a well declines, the well could potentially be drilled to a greater depth to encounter more fractures in the bedrock; however, the information in the Highlands database suggest that well yields were generally reported to be lower for wells at greater depths. This observation is typically observed in bedrock aquifers and is attributed to a general decrease in hydraulic conductivity with depth. As such, increasing the depth of a well is expected to result in variable, and potentially marginal, improvements to the well yield.

The majority of the wells in the Highlands were constructed as open boreholes in bedrock. The yields from these wells could potentially be increased using well development processes that inject water under high pressure into the borehole wall to increase the size and extent of the bedrock fractures in the vicinity of the borehole and, potentially, connect to more productive fractures within the aquifer.

12.2.2.2 Connection to an Alternate Well

Private residences could potentially connect to a nearby supply well on a neighbouring property if a well with sufficient yield were to be available; however, if a well were to be used to supply two or more residences, it would be considered a water system under the *Drinking Water Protection Act*. As such, the water system would require construction and operating permits, system operator certification, emergency response and contingency plans, water monitoring requirements, water system assessments and plans, and drinking water protection measures and plans. Although use of a well to supply more than one residence may be acceptable as a short-term measure in the event of an emergency, VIHA generally discourages such arrangements for residential wells as a long-term water supply option.

In the southern portion of the Highlands, the Hanington system could potentially be connected to one or more existing supply wells that are currently not used for drinking water supply if a formal agreement could be arranged with the owner(s) of the wells. As discussed above, the water system would be subject to the construction and operational requirements specified under the *Drinking Water Protection Act*.

12.2.2.3 Construction of a New Well

A new well could potentially be drilled on a property to supplement or replace an existing well that has a relatively low yield. The Highlands database indicates that well yield is variable throughout the Highlands, with reported values ranging from less than 0.01 litres/second (L/s) to greater than 15 L/s. These results suggest relatively high uncertainty in locating and drilling a new well that has a higher yield. This uncertainty should be considered when assessing the costs to drill a new well.

12.2.3 Surface Water

Surface water could potentially be used to as an alternative water supply source. In accordance with the *Water Act*, a license is required to divert and use surface water. In reviewing a license application, the MoE considers minimum in-stream flow requirements, determines if there is sufficient water available from the source, and assesses potential impacts to existing license holders and other interested parties.

During Phase 1 of the Study, a search of the MoE Water Resources Atlas database (MoE database) identified a total of 51 registered active surface water licenses in the Highlands, with the majority of those surface water licenses designated for domestic use (Golder Associates, 2008). Based on these results, it is anticipated that only a limited number of additional surface water licenses would be available within the Highlands. A water allocation plan that was written in 1994 for Saanich-Victoria indicated that although ample water was available during the period November through April, extra surface water storage would be required to support additional water demand during the low flow period (Walsh et al., 1994). It was recommended that the storage quantity required to support additional domestic and irrigation uses would be equal to the volume of the water demand plus an additional allowance of 0.3 m depth over the surface area of the storage reservoir to account for evaporation and other losses. Based on the potential impacts of climate change, it is anticipated that evaporation losses would increase during the longer and drier drought periods.

The results of a water detention study that was conducted by M. Miles and Associates Ltd. (2002) identified locations within the Millstream Watershed that were potentially suitable for developing sizeable detention areas for additional surface water storage. Although this additional storage could be replenished during the wet season for use as an alternative water supply and also for release during the low flow period (dry season) to support minimum baseflow, it was not considered to be a viable source for large quantities of potable water. It was concluded that further assessment was required including a monitoring program to assess stream discharges and a survey to verify existing licenses and estimate actual surface water usage. If the District were to implement these activities, it could do so in correspondence with the MoE to support a coordinated approach to assessing surface water volumes that may potentially be available through additional water licenses.

If additional water licenses were to be available, surface water would represent a viable option for properties that are adjacent to, or have access to (e.g., via a right-of-way), a surface water body. Alternatively, one or more collection stations could be established to provide access to residents or tanker trucks. It is expected that construction of a distribution system would not be feasible for the volumes of water that could be accommodated by surface water sources. Treatment requirements would also have to be considered, as surface water generally requires more treatment than groundwater. Treatment requirements also tend to increase with the amount of upstream development in the watershed.

12.2.4 Rainwater

As discussed in Section 10.2.3, rainwater harvesting can be implemented as a conservation strategy to reduce demand for groundwater. If configured appropriately, RWH systems can be used as a source of potable water for a single family dwelling. As with private wells, RWH systems for potable supply are not regulated under the *Drinking Water Protection Act* and fall outside the jurisdiction of the Health Authorities. Components of an RWH system must comply with the British Columbia Building Code and it is recommended that the installation of RWH systems be supervised by an experienced plumber or technician (Stubbs, 2006). Consideration should also be given to water treatment requirements and monitoring programs to assess the quality of the water from the RWH system.

Precipitation is significantly lower during the summer months when water demand is greatest and climate change models predict longer, drier summers in the future. Predicted precipitation patterns and other site-specific factors should be considered when sizing the volume of the cistern (storage reservoir) and system components. Further details are discussed in Section 10.2.3.

12.2.5 Capital Regional District Municipal Supply

The intent of the Highlands is for water supply to continue to be sourced primarily from privately owned individual wells, other than in the area specified as the Proposed Highlands Servicing Area in the District of Highlands OCP (Highlands, 2007). If required, the Municipal System may represent an alternative water supply source for the Highlands. Connection to the Municipal System may represent a cost-effective alternative for the Hanington System, if sufficient supply were to be available from the Capital Regional District.

The capital costs required to extend the Municipal System to individual residences north of the Hanington Creek Subdivision would be relatively high on a per capita basis. The capital costs would be particularly high to extend the Municipal System to groundwater recharge areas located at higher elevations of the Highlands, where climate change could have the most significant impact on groundwater levels (Section 8.3).

13.0 EMERGENCY RESPONSE PLANNING

The groundwater quality protection measures presented in Section 11.0 represent the technical framework to prevent contamination of groundwater supplies in the Highlands; however, even when comprehensive groundwater protection plans are implemented, unexpected events such as accidents and spills have the potential to disrupt and/or contaminate groundwater supplies. Conditions that could potentially lead to loss or contamination of water supply may include:

- Power outage – loss of regional power or local power supply disruption;
- Flooding – inundation of a well and loss of power or contamination of the water supply;
- Fire – at a well/well house;
- Contamination of source (chemical) – spills, leaks from underground or above ground storage tanks or septic systems, infiltration of nitrates from fertilization practices;
- Contamination of source (biological) – contamination of groundwater from septic fields, manure from agricultural operations;
- Earthquake – power loss, distribution line breaks; and
- Vandalism.

When the impact from an emergency event is physical in nature (e.g., distribution line break), the corrective action is relatively routine, particularly for residential water systems; however, water main breaks due to corrosion, impact or earthquakes could significantly influence private supplies and would be of particular concern to the Hanington system, which currently supplies 50 residences and will supply 60 residences at full build-out. When other conditions occur that increase the potential to contaminate the groundwater, a planned approach is recommended and may require involvement from a registered professional[4] practicing in the field of contaminant hydrogeology (a "contaminant hydrogeologist").

The objective of the emergency response planning exercise was to outline a framework to support timely and coordinated responses to emergency events and to address the potential impacts associated with events that could contaminate groundwater supplies in the Highlands. Golder reviewed the existing Highlands Emergency Program (Emergency Program) and outlined a framework to refine the Emergency Program to guide emergency response efforts to groundwater contamination in a coordinated manner. The results are presented in the following sections.

[4] Professional Geoscientist (P.Geo.) or Professional Engineer (P.Eng.) registered with the Association of Professional Engineers and Geoscientists of British Columbia (APEGBC).

13.1 Existing Emergency Response Plan

The District of Highlands Emergency Response and Recovery Plan, By Law No. 56 (Emergency Response Plan), outlines the District's "authority and responsibility to act in emergencies, and communicates policies and procedures to be followed" (District of Highlands, 2004). The Emergency Response Plan provides the operational guideline for coordinating responses to emergencies and describes the basic strategies that the District will use to coordinate activities during emergency events. The Emergency Response Plan also outlines Hazard-Specific Plans for emergencies including releases of dangerous goods, earthquakes, explosions, floods, transportation accidents, and urban and wildland fires.

The Emergency Response Plan currently does not specifically address events that could result in contamination of groundwater resources. Section 13.2 discusses the roles and responsibilities in the event of an emergency that has the potential to contaminate groundwater supplies and Section 13.3 outlines considerations for refinement of the Emergency Response Plan and development of a Hazard-Specific Plan to address groundwater contamination.

13.2 Roles and Responsibilities

Individual well owners are responsible for their individual water systems in the event of an emergency. Although the District does not have jurisdiction over individual private water supplies, the District has the overall responsibility to "coordinate the protection of Highlands citizens, property, environment, and economic well-being in a major emergency or disaster" (District of Highlands, 2004). The role of the District is to provide well owners with information and to advocate preparedness, identify conditions that could potentially result in impacts to the water supply and, in the event of an emergency, support first response activities, issue public warnings and provide information to residents.

The Emergency Response Plan outlines measures for the District to coordinate the emergency response procedures for departments including the Fire Department, Royal Canadian Mounted Police (RCMP) and BC Ambulance, and external organisations, both government and private (e.g., Public Works, Search and Rescue, contractors to the District, etc.) that may assist the District. The Emergency Response Plan also outlines the framework for an Emergency Operations Centre (EOC) Group that is staffed during emergencies to a level that matches the requirements of the emergencies (District of Highlands, 2004). As discussed further in Section 13.3.4, the District has the responsibility to keep the public informed during an emergency.

In the event of an incident that involves a spill or release of dangerous goods or an accident, fire or similar incident, the Chief of the Highlands Fire Department has the lead role for first response. For significant incidents with the potential to contaminate groundwater supplies, it is anticipated that the EOC would coordinate the efforts of the District with external organizations. Under these circumstances, it is recommended that the District obtain input from a contaminant hydrogeologist and coordinate with stakeholders such as MoE, VIHA and, depending upon the proximity to surface water bodies, Fisheries and Oceans Canada. The responsibility of the EOC is to rank and prioritize potential impacts. For the purposes of the Emergency Response Plan, addressing impacts within the area of the communal water supply well that services the Hanington Creek Estates Subdivision and in areas with relatively higher densities of private domestic wells could be considered as a first priority.

Where material is spilled in the course of business, the commercial or industrial party responsible for care and control of the material prior to the spill has responsibility for reporting and remedying the spill to the MoE under the *BC Waste Management Act*, Spill Reporting Regulation [BC Reg. 263/90]. It is anticipated that the Highlands Fire Department would also be called to the site in the event of a large spill at a business or commercial/industrial facility. Responsibility for remediation of historical releases of contaminants is described in the Contaminated Sites Regulation [BC Reg. 375/96] and generally falls to the owner of the property on which the contaminants were released.

13.3 Emergency Response Framework

The Emergency Response Plan currently does not include provisions for groundwater protection and a Hazard-Specific Plan has not been prepared to specifically address groundwater contamination. The following sections outline key considerations for refinement of the Highlands Emergency Response Program and development of an emergency response framework to guide emergency response efforts in the event that causes contamination of groundwater supplies.

13.3.1 Preparation and Coordination

In the event of an emergency, the EOC has the responsibility to coordinate response measures between District and external organisations. In preparation for such an event, the District could collaborate with these external organisations to identify what supporting information is available and to develop a framework to guide the decision making process. The objective of this exercise would be for the District to identify and document relevant information and to establish protocols to access and utilise that information, if needed in the future.

13.3.2 Measures to Mitigate Groundwater Contamination

The following sections provide the technical framework for emergency response measures that can be implemented to mitigate groundwater contamination in the event of an accident or spill.

13.3.2.1 First Response

All parties involved in a spill clean-up must recognize that a spill may not only represent an immediate danger to persons in the area, but also a danger to persons consuming groundwater. Response personnel must understand the importance of protecting groundwater resources. Without specific education on the need to protect the groundwater resource, it is unlikely that response personnel will take the necessary steps to protect it adequately. As such, response personnel should be aware of nearby wells and consider how contamination may migrate from the area of the spill. The majority of the Highlands is underlain by a fractured bedrock aquifer. Fracture networks may be variable and highly transmissive and capable of transporting contaminants at relatively rapid velocities compared to unconsolidated aquifers (e.g., sands and gravels). In the Highlands, the surficial sediments range from highly permeable colluvium, sand and gravels to relatively less permeable clay, till and organic soils. The surficial sediments are generally thin (approximately 2 to 3 m on average) and discontinuous and, as such, are inferred to provide limited protection to the underlying bedrock aquifer.

As such, spill response efforts must recognise that use of material that is mobile or increases the mobility of the spilled material in the ground (e.g., water), will increase the risk of groundwater contamination. ***Where possible, every effort should be made to contain or collect a spill, not disperse it.*** Furthermore, spill response depends upon a number of factors relating to site-specific conditions, the material spilled, weather and available resources.

If a spill were to occur in an area that is not near water supply wells, remediation could potentially be planned for a longer term than spills that occur in close proximity to one or more wells; however, because the cost of remediating contaminated soil and bedrock are relatively high and potential impacts to future groundwater use could be significant, all efforts should be made to recover the spilled material as soon as possible after the spill. The impacts of any spill and the response to it should be assessed in a follow-up phase (see Section 13.3.2.2).

With respect to groundwater protection, the most significant factor for first response efforts is whether the contaminants are in a liquid or solid form, as discussed below.

13.3.2.1.1 Liquids

As a general rule, if a liquid spill of a hazardous material or Dangerous Good[5] occurs in close proximity to one or more wells, the wells should be shut down immediately, pending further assessment of the conditions and the adequacy of the spill response. Based on the nature of the soils in the specific well area, action to contain the material may be required within hours if the groundwater supply is to be preserved.

If the product that is spilled is either flammable or immediately dangerous to life or health, it is preferable to use foam to decrease the immediate risk, if appropriate. The foam can reduce the fire risk and the mixture of spilled product and the foam can then be recovered with a vacuum tanker truck. Certain fire fighting foams contain toxic chemicals that may contaminate the groundwater supply if permitted to disperse in the ground. The Fire Department should evaluate the foam products that are normally used and consider non-toxic alternatives. When foam is used, it should be removed as soon as possible to limit the risk of groundwater impacts.

Spill response must be conducted by appropriately trained and equipped personnel or contractors. Knowledge of the appropriate level of personal protective equipment and air monitoring instruments is also essential. The Fire Department personnel who are responsible for releases of dangerous goods should have copies of HazMat response manuals to aid in the selection of an appropriate spill recovery method. Some of the methods that could potentially be used to recover spilled liquids are summarized in Table H-1, Appendix H.

13.3.2.1.2 Solids or Sludges

Spilled solids do not normally pose an immediate risk to groundwater, provided there is no mobilization condition present (e.g., heavy rainfall, fire suppression water intrusion, etc.). Spilled solids or sludges should be removed as soon as possible, before a mobilizing condition occurs. In the interim, the material should be covered with a waterproof cover to limit rainwater infiltration prior to cleanup. If the material is fine grained, wet or very hazardous, the upper layer of soil beneath the spill area should also be removed and transported to an appropriate facility for treatment or disposal. The extent of removal of such soils should be assessed in consultation with environmental professionals.

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[5] As defined in the *Canadian Transport of Dangerous Goods Act* and Regulation.

13.3.2.2 Follow-up Phase

13.3.2.2.1 Ongoing Assessment

Once the spill has occurred and initial cleanup completed or a historical spill has been determined, investigation of the contamination and its potential impact on adjacent drinking water wells is required. It is recommended that this investigation be conducted by a contaminant hydrogeologist. The objective of the investigation would be to assess potential flow paths from the area of the spill drinking water wells and the time before contaminants are expected to arrive at the wells (i.e., time-to-impact). The scope of the investigation would depend upon technical aspects such as the nature of the spill and the site specific conditions (i.e., topography, texture and thickness of overburden materials, etc.) and financial considerations.

It is also recommended that the investigation be conducted with input from MoE and VIHA. The results from the investigation should be regularly reviewed, as the status may change with time and specific measures may be required to protect public health such as water restrictions, boil water advisories or use of alternative water supplies (discussed further in Section 13.3.3).

13.3.2.2.2 Contaminant Transport and Assessment of Time-To-Impact

Investigation of a spill and its effect on adjacent drinking water wells should be commenced in consultation with a contaminant hydrogeologist. The objective of the investigation would be to assess potential flow paths from the area of the spill to drinking water wells and the time before contaminants are expected to arrive at the wells (i.e., time-to-impact). The scope of the investigation would depend upon technical aspects such as the nature of the spill and the site specific conditions (i.e., topography, texture and thickness of overburden materials, etc.) and financial considerations.

Where feasible, consideration should be given to the installation of monitoring wells between the area of the spill and nearby drinking water wells. It would be preferable to install the monitoring wells at locations that permit sufficient time to receive analytical results from an analytical laboratory, collect and analyse confirmatory samples, review the results and make a decision to discontinue use of a drinking water well; however, as discussed in Section 13.2.3.1, contaminant migration in fractured bedrock aquifers is highly variable. As a result, it is possible that contaminants from a spill could be transported through fracture networks that are not necessarily intercepted by the monitoring wells and the resulting groundwater monitoring program would not detect contaminants that are migrating towards drinking water wells. The level of uncertainty should be assessed by the contaminant hydrogeologist and the investigation and monitoring program should be designed to mitigate the potential risks.

13.3.2.2.3 Mitigation Measures

If contaminants are detected in the groundwater in areas that are adjacent to drinking water wells, it may be possible to implement measures to mitigate the impact to drinking water supplies. The selection of a mitigation measure will depend on the properties of the contaminant and the nature and extent of the release. Mitigation measures are designed to limit the transport of contaminants from the source area, intercept and/or treat groundwater between the source and the well, and treat groundwater at the drinking water well. Details regarding select mitigation measures are presented in Table H-2, located in Appendix H.

A contaminant hydrogeologist and/or remediation engineer should provide input to the selection of the most appropriate mitigation method.

13.3.2.2.4 Spill Recording

A record of all spills to ground should be maintained, with the details of the spill included in a contaminant inventory. This information will supplement the records that are registered on the BC Contaminated Sites Registry[6] and would provide guidance on allocation of groundwater protection efforts, as required.

13.3.3 Water Supply Loss Mitigation and Replacement Alternatives

Two major issues with respect to loss of a supply source are alternative supplies and delivery method. For water supply systems, supply alternatives are typically implemented in conjunction with conservation measures to reduce demand. Alternative water supplies are considered in Section 12.0. For the purposes of emergency response efforts, one or more short-term alternative water supplies could be used, depending upon the nature of the contamination. Considerations specific to emergency response efforts are discussed in the following sections.

13.3.3.1 Bulk Water Delivery

Bulk water may be the most practical and cost-effective to deliver clean drinking water in the event of a short-term emergency. Consideration could be given to establishing an emergency priority protocol with local water delivery companies.

Bulk water could either be distributed either with tanker trucks or with bottled water delivery. Tanker trucks should either be specifically designed for hauling water or are of a grade that is satisfactory to a Health Officer. Tanker trucks could be used to deliver water to the points of consumption or to potable water stations where residents can obtain drinking water.

Bottled water is likely the most effective way to deliver, in a controlled manner, a set amount of drinking water to residential users. The water can be delivered from remote sources to individual addresses or to a central staging area.

13.3.3.2 Alternate Groundwater Sources

Supply wells in the Highlands are typically constructed as open boreholes in the same fractured bedrock aquifer. A spill or release of hazardous material could result in contamination of a relatively large area within the aquifer. When assessing alternate groundwater sources, a contaminant hydrogeologist should be consulted to assess the potential for neighbouring wells to be at risk of contamination.

The Hanington system is currently supplied by Well 409 (Well Tag No. 85183) and Well 500 (Well Tag No. 85184) is designated as a backup well. If the supply from the primary well were to be contaminated, the backup well could potentially be operated as an alternate supply; however, the backup well is in relative close proximity to the primary well, at a distance of approximately 150 m, and would most likely also be contaminated.

[6] The Site Registry is a database that is maintained by the BC Ministry of Environment for the purposes of listing sites that have been assessed with respect to contamination status. Access to the Site Registry is available through BC Online at https://www.bconline.gov.bc.ca.

Within the southern portion of the Highlands, there are existing supply wells that are currently not used for drinking water supply. These wells could potentially be connected to the Hanington system to provide additional capacity or could be used as a source for trucking water. A formal agreement would need to be arranged between the operator of the Hanington system and the well owner. Furthermore, the quality of the water that is supplied by the proposed well and potential treatment requirements would have to be considered.

Private residences could potentially connect to a supply well on a neighbouring property if a well with sufficient yield were to be available. If a well were to be used to supply two or more residences, it is recommended that a water sharing agreement that outlines the terms and conditions of the water use be agreed to by the parties involved. Furthermore, if a water supply system were to be used to supply two or more residences, the system would be considered a water system and subject to the operational requirements specified in the *Drinking Water Protection Act*. These considerations are considered further in Section 12.2.2.2.

13.3.3.3 Surface Water Sources

The Hanington system and, depending upon the location, private residences could also potentially obtain temporary water supply from surface water sources. As discussed in Section 9.1.2, authority to divert and use surface water is obtained by a licence in accordance with the *Water Act*. The MoE offers a "Quick Licensing" process to fast track water licence applications for small quantities on sources where withdrawals would have no impact on other water users. This process could potentially facilitate applications for surface water licences during emergency situations.

Surface waters also generally require additional treatment compared to groundwater. Therefore, the requirements to install or upgrade water treatment facilities should also be considered.

13.3.3.4 Capital Regional District Municipal Supply

The Municipal System extends to the City of Langford, to the immediate south of the Highlands. Temporary distribution lines could potentially be used to extend the Municipal System distribution network to the Hanington system. Based on the population density in the Highlands it is not likely feasible to connect individual residences to the CRD system with a temporary pipeline; however, trucking of water to these residences may be a practical short-term alternative. Considerations associated with the Municipal System are discussed further in Section 12.2.5.

13.3.3.5 Water Supply Treatment

Where a water supply source has been contaminated, a short-term method of restoring the supply may be to add a package water treatment unit at the wellhead, reservoir or point of use. For certain contaminants, this is a reasonable alternative; however, there may be significant delays in establishing a reliable water treatment system at the wellhead or reservoir, depending upon the nature of the contamination and the volumes of water to be treated. Therefore, the most common point-of-use treatment method considered is boiling water for bacteriological contamination.

13.3.4 Communication Protocols

In the event of an emergency, the District has responsibility to guide and coordinate emergency response efforts, notify appropriate officials and keep the public informed. The District could consider developing a communications protocol specifically to address events that result in groundwater contamination. This protocol would identify lines of communication with the appropriate internal and external stakeholders to direct a coordinated response to emergency events and to guide the decision making process. The protocol would also provide input to the response guidelines in the Emergency Response Plan and support a consistent communication strategy with the public. Mobley et al. (2010) identify several essential considerations to develop a successful communication strategy to communicate the risks of contamination. The following considerations would be appropriate to the Highlands:

- Build and maintain relationships with stakeholders and other agencies;
- Prepare and organize prior to an emergency situation;
- Identify staff roles and responsibilities during the emergency; and
- Create communication templates that can be easily transferred among multiple scenarios.

Although Section 5 of the Emergency Response Plan outlines response guidelines for emergency events, the District could consider refining this framework to clarify communications protocols specifically in the event of groundwater contamination. This should include contact information for both internal, external stakeholders such as MoE and VIHA, and companies that can provide specialised technical services such as remediation contractors and contaminant hydrogeologists.

13.3.5 Resources

Resources are required to establish and implement the emergency response measures discussed in the preceding sections. In particular, the District should consider the resources required for the following items:

- Update the existing Emergency Program;
- Logistical support comprising a team of individuals who are trained to implement response measures;
- Personnel and technical resources including an emergency call-out roster that identifies key personnel and/or organizations that can organize the required resources for various types of emergencies and to coordinate the response efforts;
- Equipment and materials resources including a list of equipment suppliers and qualified operators;
- Financial resources; and
- Public communications/community relations.

Further details regarding the above items are provided in Table H-3, Appendix H.

PART IV: FRAMEWORK FOR IMPLEMENTATION OF CONSERVATION AND GROUNDWATER PROTECTION MEASURES

The results from the current Study, including the refined numerical model, provide the technical framework for the conservation and groundwater protection initiatives presented in Part III of this report. Successful implementation of groundwater conservation and protection measures requires clear objectives, a manageable scope of activities and designated roles and responsibilities. The District will require buy-in from Highlands residents, a staff commitment and Council support. It is anticipated that the District will need to prioritize conservation and groundwater protection efforts and develop an implementation plan that is appropriate to the staff and volunteer resources required and the financial resources available.

To support implementation in a cost-effective and coordinated manner, it is recommended that the District identify opportunities to collaborate with initiatives both internal and external to the Highlands. In accordance with HSTF Recommendation 41, the District could explore options to implement water conservation and groundwater protection initiatives in collaboration with existing networks within the community. For example, the District could consider coordinating groundwater monitoring activities and the activities of the Highlands Stewardship Foundation (HSF) to mitigate volunteer burnout, encourage efficient use of resources and equipment, and support effective data management.

As outlined in HSTF Recommendation 42, the District may also wish to consider opportunities to engage external organisations and develop networks within the broader stakeholder community. The District could consider options to strengthen collaboration with ministries in the provincial government (e.g., MoA, MoE, MoH, etc.), other local governments that are active in groundwater conservation and protection such as the RDN, CVRD and Gulf Islands Trust, City of Kelowna and OBWB, academic institutions such as UVic, Vancouver Island University (VIU) and Royal Roads University (RRU), industry associations such as the BC Water and Waste Association (BCWWA), and partnerships such as Waterbucket and Convening Action on Vancouver Island (CAVI). Active networking with external stakeholders will provide the District with information regarding the successes and challenges experienced in other jurisdictions and provide the District with opportunities to provide input and guide initiatives. The District actively participates in the Union of BC Municipalities (UBCM). Other mechanisms by which the District can engage external stakeholders include participation in workshops, committees, working groups and networking venues.

Sustainable funding will also be required to conduct technical studies, for the consultation and planning process, the staffing required to implement the measures, and for ongoing management and monitoring. The District should develop an estimate of the potential costs to implement the conservation and groundwater protection measures. Based on the resources available, measures could then be implemented using a phased approach. Funding for groundwater protection initiatives may be available from a variety of sources. For example, the current Study was funded through the Gas Tax Agreement. Under the Living Water Smart Plan, the government of BC will provide funding to encourage conservation including funding for household water evaluations, funding summer jobs and awarding prizes and scholarships for excellence in stewardship (Living Water Smart, 2011). It is anticipated that Highlands would be well positioned to apply for these funds. The District could also pursue opportunities to collaborate with other local governments and provincial agencies to identify opportunities to share resources and/or funding for initiatives such as monitoring programs.

Based on the priorities of the Highlands and the resources available, the District should develop a framework for implementation of the recommendations presented in the following sections.

14.0 RECOMMENDATIONS

14.1 Public Education and Communications Strategy

Public education and involvement can be one of the most important conservation and groundwater protection measures, particularly in communities like the Highlands where water is supplied from privately-owned wells. The goals of a public education and communications strategy are to raise awareness, educate well owners and residents about the importance of groundwater conservation and protection, and to provide information and tools that encourage changes in behaviour. Education initiatives should be developed with consideration of the target audiences and the desired outcomes. As discussed in the following sections, the education strategy should engage the community, provide clear messages and use a range of tools that are suitable for the Highlands.

14.1.1 Effective Leadership and Committed Participants

Although the volunteer base in the Highlands is relatively strong, one of the key challenges will be engaging the broader community. Research has shown that people are more likely to support water conservation when they have made a nominal commitment to the cause (e.g., wear a button or sign a petition) (Silva et al., 2010). In conjunction with the public education measures discussed in Section 14.1.3, the District could consider making a formal commitment to groundwater protection and encouraging residents to make a personal commitment by signing a pledge. This initiative could be used to generate interest in the community or emphasize new programs and would demonstrate the District's leadership and encourage commitment at the household level. The District could use existing resources to develop a local tool. For example, the ActionH2O Water Sustainability Charter toolkit provides the framework for local governments to commit to supporting local water conservation goals (Porter-Bopp, 2010). The City of Abbotsford developed both Business Environmental Pledge and Residential Pledge programs (City of Abbotsford, 2012).

14.1.2 Content and Messages

Technical information from programs such as the current Study and the Highlands Integrated Community Sustainability Plan (ICSP; Whistler Centre for Sustainability, 2011) represent a clear and factual basis for a public education strategy. The results from these programs should be presented in a manner that is relevant to the local context to generate interest and encourage involvement.

It is anticipated that the content for an education and outreach strategy would range from general public awareness to information related to particular aspects identified in Part III of this report. It is recommended that the District rank groundwater conservation and protection initiatives to prioritize efforts. Public education measures could then be developed to support implementation in a coordinated manner that focuses efforts on key initiatives. Educational materials for specific aspects such as household water consumption, wellhead protection or BMPs should identify the importance of the topic, provide linkages to the tools and information that will enable well owners to implement conservation and protection measures, and emphasize the benefits to the well owner.

14.1.3 Methods and Tools

A variety of educational methods and tools could be implemented to generate interest and to engage the various target groups in the Highlands. Based on the relative ranking that the District assigns to conservation and protection initiatives, the District could develop an education strategy that uses existing tools both internal and external to the Highlands and includes provisions to develop specific tools, as required, to customize the information for the local context. This approach would enable the District to focus efforts and financial resources in a targeted manner. It is anticipated that the education strategy would use a variety of tools that could include the elements presented in the following sections.

Signs

Signs can be used to raise public awareness and provide reminders to residents. For example, road signs have been used in the Cowichan Valley Regional District (CVRD) and communities in the Gulf Islands to inform motorists when they are entering areas that are designated as groundwater protection areas.

Fact Sheets and Technical Resources

A number of existing fact sheets and technical resources are available from external stakeholders. For example, pamphlets and fact sheets regarding well construction and groundwater quality are available from the MoE (MoE, 2011b). The RDN and Township of Langley have developed information brochures regarding septic system maintenance and the Gulf Islands Trust partnered with Natural Resources Canada (NRC) to develop Waterscape Posters that illustrate water issues for communities on the Gulf Islands (Natural Resources Canada, 2011). These types of existing tools could be provided to Highlands residents or the District could engage these external stakeholders to explore the possibility to refine these existing tools to make them specific to the Highlands.

Highlands Newsletter and Brochures

The monthly Highlands newsletter provides residents with information regarding various programs and initiatives in the Highlands. In conjunction with HSTF Recommendation 39, the District could consider adding a Sustainability section to the Highlands newsletter and providing regular coverage of conservation and groundwater protection topics, with references for further information that is available through on-line resources, as discussed below.

Website and On-line Resources

The District has developed a “Highlands Sustainability” page on its website to provide information on sustainability initiatives in the Highlands. A Facebook group has also been formed for Highlanders to exchange information and ideas.

In addition to the information and links that are presented on the District’s website, many tools that would be applicable to the Highlands are available on-line from external stakeholders. For example, the City of Kelowna and RDN websites provide viewers with information on a variety of water-related topics and projects.

These websites provide residents with the opportunity to learn about the issues and initiatives that are being implemented in their respective communities; however, the information can be spread out in a variety of locations and members of the public may not be inclined to regularly research the latest developments in conservation and groundwater protection. The District could consider updating the Highlands website in conjunction with HSTF Recommendation 40 to include a conservation and groundwater protection page that provides both information specific to the Highlands and links to other initiatives and relevant resources. For example, the Highlands could provide links to existing tools such as household water use calculators that are available on the zerofootprint and Environment Canada websites, manuals such as the City of Guelph (2011) Residential RWH Design and Installation Best Practices Manual, and initiatives that are being undertaken in local communities such as the wellSMART and SepticSmart programs in the RDN (RDN, 2011a). It is recommended that the District also consider ways to remind residents of the on-line resources available and to provide regular updates. This could be accomplished through a variety of mechanisms including updates in the Highlands newsletter or regular email updates.

Reports and Studies

The results from studies and initiatives provide the technical basis for conservation and groundwater protection programs. In addition to the public presentations discussed below, the District also makes technical reports from programs such as the current Study and Sustainable Highlands available on the Highlands website. The District has also developed summary documents or synopses to inform residents of the key findings and recommendations from these studies. For example, the Sustainable Highlands Summary Document is posted on the Highlands website.

Public Presentations, Seminars and Workshops

These events provide the opportunity to engage local stakeholders and provide information required to support behavioural changes. The District hosts technical workshops and organizes technical presentations to provide residents with opportunities to learn about studies and programs in the Highlands. The District could consider organizing workshops that provide residents with information required to implement specific conservation or groundwater protection measures discussed in Part III of this report. The District could also explore opportunities to collaborate with other local governments and organizations to share materials or resources for initiatives such as the free workshops that the RDN has organized to inform participants about key topics such as pesticide-free gardening practices, rainwater harvesting and grey water use, irrigation system maintenance and low irrigation landscaping (RDN, 2011a).

Educational Programs

Golder provided technical assistance to the District in the preparation of educational materials such as a poster display and a groundwater component for the Highlands Community Green Map (Highland District Community Association, 2008). The District could consider opportunities to display these and other educational materials regularly at local events such as the Highlands Farmer's Market and the annual Highlands Fling. The District could also consider opportunities to provide information to families through programs for grade school children. For example, Oxford County, ON hosts and annual Children's Water Festival to raise awareness for conservation and groundwater protection and to provide hands-on learning with exhibits, displays and games to over 3,000 grade school students (Oxford Children's Water Festival, 2011). The District has also worked collaboratively with students on previous initiatives such as well audits. In the future, the District could consider options to hire students as outreach coordinators and to assist with certain initiatives such as the proposed household audit program (Sections 10.2.1 and 11.2.1) or upgrading the website. Funding for these positions may be available from external sources such as the Living Water Smart initiative which includes plans for the provincial government to provide summer jobs for youths between the ages of 16 to 22 (Living Water Smart, 2011).

14.1.4 Implementation

The District should consider the merits, costs and challenges associated with the various options discussed in the preceding section to develop an education strategy that includes the right combination of methods and tools. An education strategy should be implemented consistently, over a period of time, as one-time announcements are less likely to generate and sustain interest, particularly when targeting individual behavioural change. Education initiatives for conservation and groundwater protection should be developed as components of a more comprehensive sustainability communication and education strategy proposed as HSTF Recommendation 38.

14.2 Groundwater Monitoring

Data from the Highlands Groundwater Monitoring program and stakeholder monitoring programs have established baseline conditions, including the seasonal variability, across the Highlands. Golder recommends that the District continue to monitor groundwater conditions in the Highlands using a coordinated approach that includes ongoing collection of continuous water-level data from Highlands monitoring wells and continued collaboration with stakeholders to obtain water-level and precipitation information from the respective monitoring programs. The District should also obtain water quality data from select land owners to monitor potential changes to water quality in the southern portion of the Highlands.

The data from the Highlands and stakeholder monitoring programs should be compiled and reviewed on an annual basis to assess long-term trends. If trends are observed, the results would provide the basis to guide implementation of management strategies including the conservation and groundwater protection measures discussed in Sections 10.0 and 11.0, respectively, and the public education and communications efforts that are discussed in the preceding section. If, in the future, the results from the groundwater monitoring program are significantly different from those predicted by the numerical model, the model should be refined with updated data and information.

14.2.1 Water-Level Monitoring

It is recommended that the District continue to collect continuous water-level data from Highlands monitoring wells DOH-01, DOH-02A, DOH-03, DOH-04B, DOH-07B and DOH-09A to assess longterm trends and to confirm the predicted effects of development and potential impacts of climate change. The water-level data will provide a valuable data set for future refinement of the numerical model, if required. The District should also obtain water-level and precipitation data from stakeholder monitoring programs. The local precipitation monitoring data could also be used for refinement of the model in the future.

Highlands monitoring wells DOH-02A and DOH-07B are privately-owned wells. The owners of the wells have volunteered use of their wells for monitoring purposes; however, the District may wish to establish new monitoring wells at nearby locations on District-owned properties in order to secure long term access to monitoring wells. If so, it is recommended that the inventory of unused wells first be reviewed to identify new monitoring wells. If suitable unused wells are not identified, new wells could be drilled.

Based on the results of the numerical model, the potential impacts of climate change are predicted to be most noticeable towards the end of the dry season at upper elevations along the northern and central portions of the Highlands. Although the existing monitoring well network generally provides coverage across the developed portions of the Highlands, the District may wish to conduct detailed water-level monitoring in the areas of monitoring well DOH-05 and DOH-10. As wells DOH-05 and DOH-10 are privately-owned and used for domestic water supply, it is recommended that either unused wells be identified or new wells be drilled to establish long term monitoring points in these areas.

It is also recommended that the extent of the northwest-trending lineament in the area of the Bear Mountain Golf Course be further investigated if this area is identified as a potential area for development. The results of the investigation would provide the basis to refine estimates of groundwater flow in the southern portion of the Highlands and to facilitate the collection of continuous water-level data required to assess conditions in this area. This could require drilling and installation of several observation wells near the currently defined limits of the lineament.

14.2.2 Groundwater Quality Monitoring

Under the Contaminant Inventory that was compiled in Phase 2 of the Study, current and historical activities on C/I properties, in the southern portion of the Highlands, were identified as potential sources of groundwater contamination that received the highest priority ranking. As such, it is recommended that the District coordinate with the CRD and site operators at C/I properties to discuss opportunities to share information from the water quality monitoring programs that are being undertaken at the respective properties.

Application, use and storage of chemicals including fertilizers, herbicides or pesticides are potential hazards to groundwater quality in the southern portion of the Highlands. Also, operators of the Bear Mountain Golf Course had proposed to construct a wastewater treatment plant that will serve the proposed Bear Mountain development (Focus, 2009). If the proposed facility is constructed and operated, reclaimed treated wastewater from the facility would be used to irrigate the golf course. Introduction of residual pharmaceuticals from the reclaimed treated wastewater would represent a potential hazard to groundwater quality.

Requirements for groundwater monitoring, including analysis for concentrations of residual pharmaceuticals if the proposed wastewater treatment plant is constructed and operated, are outlined in the Master Development Agreement (MDA) between the Bear Mountain Master Partnership (formerly LGB9 Development Corporation) and the District (District of Highlands, 2005). Golder recommends that the District obtain and review results available from the Bear Mountain water quality monitoring program on an annual basis to assess groundwater conditions in the southern portion of the Highlands and to assess the effectiveness of the BMPs to protect groundwater quality.

Other potential sources of groundwater contamination in the Highlands include the use, storage and disposal of chemicals and hazardous products, septic systems, fuel storage tanks and hobby farming on rural and rural residential properties; however, a water quality monitoring program across the Highlands to assess potential contamination from these sources would be costly to implement. Therefore, it is recommended that the District encourage private well owners to regularly sample their wells, particularly if the owner has concerns regarding the quality of the water from their well.

The District should compile available water quality data that are provided by residential well owners, the Bear Mountain Golf Course, operators of C/I properties and developers in a database, as discussed in Section 14.3.

14.2.3 Flow Monitoring

It is recommended that the District obtain and review the groundwater pumping data from the Bear Mountain Golf Course and the Hanington Creek Estates Water System on an annual basis. As discussed in Section 10.0, the District may also consider implementing a program to install flow meters on a sample of individual private wells to monitor groundwater consumption in the Highlands. If installed, the data from the residential flow meters should be reviewed on an annual basis to assess seasonal patterns and potential relationships between residential groundwater use and inter-annual variation in precipitation, long term trends and/or the effectiveness of conservation measures, when implemented.

14.3 Contaminant Inventory Review

Additional information is required to assess the nature of on-site facilities and land use practices at the Bear Mountain Golf Course and where home-based businesses and hobby farms have been identified. It is recommended that the District work with property owners to implement the use of BMPs for the land uses at their respective properties. Practices on the C/I properties in the southern portion of the Highlands should also be reviewed to assess potential changes that may potentially introduce contaminants to the groundwater. Based on the results of these activities, and in conjunction with the monitoring activities described in the preceding section, the District should refine and review the results of the contaminant inventory on an annual basis. The priority rankings that were assigned in Phase 2 of the Study should be revised to reflect the new information and to guide implementation of groundwater protection efforts such as technical assistance programs and the communications strategy (Section 14.1).

14.4 Database System

The Highlands database provides details for wells across the Highlands. The District may wish to consider building upon the Highlands database and establish a centralised database system to store and manage data from the monitoring programs and supporting information including land use practices and the results from the contaminant inventory, results from conservation and groundwater protection measures, records regarding spills and/or emergency response programs.

14.5 Legislative Review

In February 2012, Council approved the Highlands ICSP and the District is currently reviewing the OCP to identify opportunities to integrate elements of the ICSP into the OCP. It is recommended that, in support of this process, the results from the current Study inform the OCP review process. The District should consider regulatory measures that would support aquifer-scale planning and implementation of the groundwater conservation and protection measures that are presented in Sections 10.0 and 11.0. The OCP review should also consider amendments to supporting legislation such as zoning, land use designations, DPAs and bylaws that would be required to support implementation of conservation and groundwater protection efforts in a consistent and coordinated manner.

14.6 Emergency Response Planning

Based on the information presented in Section 13.0 of this report, it is recommended that the Highlands review and revise the Emergency Response Program where necessary to address events that could potentially result in a loss of water supply or contamination of groundwater resources. The program should be reviewed and updated regularly (e.g., annually) to revise the details of the program, if required.

The roles and responsibilities associated with groundwater related activities should be reflected in the Highlands Emergency Plan, including the Response Guidelines. The roles and responsibilities of outside agencies such as the MoE and VIHA should also be discussed with the respective agencies and assigned in the Emergency Response Program documentation.

The existing Hazard-Specific Plans for Dangerous Goods Release, Flood, and Transportation Accident – Road should be revised to reflect the first response measures that are outlined in Section 13.0. It is also recommended that the District prepare a Hazard-Specific Plan for groundwater contamination to outline the first response and follow-up activities that are required to prevent groundwater contamination.

The database system discussed in Section 14.4 should provide a list of technical specialists, bulk/bottled water suppliers and contractors that provide spill response, remediation and water treatment services. These contractors should include excavators, drillers, pump/vacuum trucks, dump trucks, potable water tankers, well drillers, waste disposal contractors, and suppliers of water treatment plants, absorbent materials and other remediation supplies.

It is recommended that the District also maintain a list of streams in the Highlands that are designated as eligible or excluded by the MoE for the Quick Licensing process. Up to date information on eligible streams would facilitate the decision making process in the event that surface water sources are required in the event of an emergency.

15.0 LIMITATIONS AND USE OF THIS REPORT

This report was prepared for the exclusive use of the District of Highlands. In evaluating the requirements of Phase 3 of the Groundwater Protection Study, Golder Associates Ltd. has relied 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 visits 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 detailed 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.

16.0 CLOSURE

We trust this report provides you with the information you require at this time. Should you have any questions regarding the contents of this report, or require any further information, please do not hesitate to contact the undersigned.

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