Yukon
Environment

PROTOCOL FOR THE CONTAMINATED SITES REGULATION UNDER THE ENVIRONMENT ACT

PROTOCOL NO. 7:
Groundwater Monitoring Well Installation, Sampling, and Decommissioning

Prepared pursuant to Part 6 – Administration, Section 21,
Contaminated Sites Regulation, OIC 2002/171

GROUNDWATER MONITORING WELL INSTALLATION, SAMPLING, AND DECOMMISSIONING

1.0 Introduction

The Yukon *Contaminated Sites Regulation* (CSR) (OIC 2002/171) under the Yukon Environment Act contains requirements to ensure that groundwater at a site is suitable for direct use, based on groundwater use at the site, and is of adequate quality to protect adjacent groundwater users. The following protocol is designed to ensure that appropriate and consistent standards are used for groundwater monitoring well installation, sampling, and decommissioning in Yukon.

This protocol has been adopted in accordance with Section 21(1)(b) of the CSR, which authorizes the Minister or his/her delegate to approve or adopt protocols for sampling soil, sediment, water, snow and other environmental media. For more detailed information on these topics please refer to the Yukon Technical Guidance document entitled: **Groundwater Investigation and Characterization.**

2.0 Installation of Groundwater Monitoring Wells

2.1 Conventional Monitoring Wells

For site assessments, monitoring wells are commonly installed to acquire groundwater samples and facilitate water-level measurements. Conventional monitoring wells are commonly composed of a riser pipe inserted into a drilled borehole, and a screened completion interval at the base which is placed within a targeted geologic unit. The well screen is enveloped in a sand filter pack, and is isolated from the overlying borehole and geologic units by an annular seal (commonly bentonite). Additional information regarding the installation of groundwater monitoring wells can be found in the American Society of Testing and Materials (ASTM) standard **D5092-04e1 Standard Practice for Design and Installation of Ground Water Monitoring Wells**. Use of this ASTM standard is acceptable in Yukon***.*** Any deviation from the requirements provided in the standard or presented below must be identified, together with supporting rationale.

Well Drilling Methods

Well drilling methods commonly used and acceptable in Yukon include air rotary, sonic drilling, cable tool, hollow and solid stem auger, direct push, and Becker hammer. The method selection is usually dictated by the anticipated ground conditions and the availability of equipment. Whenever feasible, drilling procedures should be utilized that do not require the injection of water or drilling fluids into the borehole, and that optimize cuttings control at ground surface. Where the use of drilling fluids is unavoidable, the selected fluid should have as little impact as possible on the water samples for the constituents of interest. When fluids are to be added, the fluids are to be free of the contaminants of concern or potential concern and, if uncertain, require sampling and analysis to confirm the absence of contaminants.

Well Diameter

Conventional monitoring well diameters can range from 25mm (1 inch) to 150mm (6 inch), with 50mm (2 inch) being the most common. The selected well diameter should be the minimum practical size that will allow proper development of the well filter pack and operation of the sampling device. Large diameter wells (greater than 50 mm) may be used but are not recommended as they hold large volumes of water that may require purging prior to sampling.

Well Materials

Monitoring wells are to be constructed of inert materials that will not compromise the quality of sampled groundwater, and will not deteriorate over time whilst in contact with formation soil, groundwater and contaminants. The most commonly accepted well material used in Yukon is polyvinyl chloride (PVC) plastic. However, caution is advised that certain contaminants (e.g., pure phase xylenes, or ketones) can melt PVC plastic and other materials (e.g., stainless steel) may be necessary. Wall thicknesses (e.g., schedule 40 or 80 are most common) should be selected to avoid breakage during and following installation.

Well Screens and Filters

After drilling, the assembled monitoring well including the riser pipe and affixed screen are placed into the borehole to the desired depth. A filter material, which is typically a sand, should be placed around the screen to serve as a filter pack that will remove particulates during sampling. Well screen slot size should be based on hydraulic characteristics and on the grain-size distribution of the aquifer being monitored. The filter pack should be a chemically inert material, well rounded, and uniform in size. The filter pack material should be placed in the annular space between the well screen and sides of the borehole, preferably using a tremie pipe, to create a filter zone of at least 50 mm between the well screen and borehole sides. The filter pack should be placed from the base of the well screen to at least 300 mm above the top of the screen. A seal, such as hydrated bentonite chips or pellets, should then be placed to a minimum of 300 mm above the top of the filter pack. The remainder of the borehole annulus is then to be filled with an inert low permeability material as described below, and then sealed at ground surface with a hard seal such as concrete to prevent infiltration of surface water and to provide well protection.

Well Sealants

Recommended sealants above the filter pack and along the well annulus include non-shrinking bentonite-based grouts or solids. In cases where granular bentonite, bentonite chips, or bentonite pellets are utilized, proper hydration of the bentonite during placement should be ensured, particularly if the seal is located in the unsaturated zone.

2.2 Well Screen Length and Completion Interval

The length of the well screen should be limited to the thickness of the affected portion of the hydrostratigraphic unit to prevent the introduction of a pathway to other stratigraphic units. Based on site-specific information obtained during the site assessment, monitored depth intervals (i.e., well screen length plus filter pack) in each aquifer may range from a few centimetres to a few metres, recognizing that dilution of constituents is likely to occur for the longer well screens.

For installations where the completion interval is completely below the water table, saturated well screen intervals should not exceed 1.8 m. Where a water table aquifer is monitored, the screen length should not extend beyond a depth of one metre below greatest depth to the water table as defined by the seasonal minimum. Chemical data for samples from wells with saturated completion intervals in excess of 1.8 m should not be compared directly with groundwater quality standards unless supporting rationale can be provided. Any deviation from these requirements must be identified and justified with supporting rationale.

Preference should be given to much smaller intervals, on the order of 0.3 m or less, so that any expected averaging effect at a receptor (e.g., a water supply well) can be established. In aquifers where the contamination may exceed one to two metres in thickness, multiple wells completed in well nests, or vertical groundwater profiles, should be completed to define conditions over the depth of the aquifer. For conventional well nests, each depth interval should be monitored by a single well installed in a separate borehole. Multiple conventional 50 mm diameter wells should not be installed in the same borehole as appropriate seals cannot be effectively installed, and therefore the installation can pose a significant risk of hydraulic cross communication and/or cross-contamination. Under certain conditions (e.g., collapsing sands), multi-level wells in the same borehole can be installed using narrow diameter pipe or tubing, or using commercially available products that allow separate depth intervals to be effectively sealed.

2.3 Wells Installed in NAPL

Caution should be exercised when drilling, installing and sampling wells suspected to contain Non-Aqueous Phase Liquid (NAPL). Many NAPLs are clear and colourless, or are easily missed because they co-dissolve natural organic materials, taking on the same colour as the surrounding medium. If suspected, meticulous care should be taken to avoid cross contamination and drawdown from one water bearing unit to another. This may be achieved by the installation of a double-cased well. This is the use of a larger diameter borehole and casing, which is drilled into a confining layer, sealed with grout from the bottom to ground surface, and once cured, is drilled through to the lower unit. Double cased wells are also used when there is reason to believe that interconnection of two aquifers by well construction may cause cross-contamination or when a highly contaminated surface soil zone can be cased off so that drilling can continue below the casing with reduced danger of cross-contamination. Once the well is installed, monitoring should be conducted to determine NAPL presence. Special probes, such as an interface meter may be inserted into the well to verify the presence and thickness of any Light Non-Aqueous Phase Liquid (LNAPL) or Dense Non-Aqueous Phase Liquid (DNAPL). Alternatively, special bailers and/or oil-finding pastes may be used.

2.4 Well Installation in Permafrost

Groundwater in some regions of Yukon may occur as supra-permafrost water (water above permafrost within thawed ground during summer months, and which is frozen during the winter), sub-permafrost water (water within the thawed zone beneath permanently frozen ground), or intra-permafrost water (water within thawed zones between masses of frozen ground).

Key principals to consider when installing monitoring wells in permafrost areas or frost susceptible soils include:

- ***Minimize effects on the subsurface thermal regime.*** Monitoring wells and well points must be designed and constructed to minimize effects on the subsurface thermal regime (permafrost) and to withstand freeze-thaw forces (seasonal frost). Caution should be used when installing a well through permafrost that may be acting as a confining unit because flowing artesian conditions may occur. ***The thawed annulus between the pipe and the***

permafrost must be firmly sealed to prevent seepage upward from the confined aquifer. In monitoring wells completed below permafrost, groundwater that rises in the casing up into the permafrost or frozen ground zone may freeze.

- ***Maintain wells to allow sample collection at the time of year when sampling is necessary.*** In some locations there may be a seasonal or localized hydraulic connection or window between the supra-permafrost and the sub-permafrost zones. In these situations, monitoring wells may need to be installed within the sub-permafrost. Unique permafrost conditions create requirements for specifically designed and constructed monitoring wells. As sub-permafrost groundwater rises in the well to equal the local potentiometric surface, it will pass through the permafrost zone (which is typically at a temperature of -0.5ºC to -1ºC). If water remains in the well without movement, it will freeze in the well casing thereby preventing sampling.
- ***Seal the annular space between the riser pipe (i.e., well casing) and any permafrost to prevent upward seepage.*** If monitoring wells are to be installed in the sub-permafrost zone or in an area that has a history of flowing wells, artesian conditions may be expected. Drilling contractors should be engaged that have capability and expertise to prevent a well from flowing out of control, and to stop the flow of water if it occurs. ***If artesian conditions are suspected, precautions should be taken during well design and installation to accommodate, and be compatible with, the appropriate device (e.g., a control valve) to control the discharge of water.*** The device must be capable of stopping the flow of water from the well casing and withstanding the freezing of water in the casing.

2.5 Water Levels and Elevation

Water level and elevation data should be acquired from monitoring wells that allow such measurements. At a minimum:

- All wells must be surveyed with reference to an elevation datum (a geodetic datum is preferred, although a site-specific reference datum may be acceptable in remote locations).
- Static water levels must be measured on the same day from monitoring wells at several locations within the same aquifer.
- The elevation data must be tabulated.

If such data are not obtained, supporting rationale must be provided as to why the data is not necessary.

2.6 Groundwater Flow Direction and Velocity

The groundwater flow direction and velocity should be established as part of the site assessment, and the data used to re-assess the actual sampling locations with respect to locations anticipated to have highest concentrations*.* Groundwater flow direction should be estimated using water-level measurements acquired from a minimum of three locations arranged in a triangular plane within the same hydrogeologic unit (i.e., the same aquifer). Caution is advised, however, where groundwater flow patterns are complex (e.g., where groundwater mounding may result in radial flow, in fractured rock situations), as data from more than three wells will be necessary to resolve flow directions.

3.0 Sampling Practices

Additional information regarding obtaining samples from a groundwater monitoring well can be found in ASTM standard **D4448-01 Standard Guide for Sampling Ground-Water Monitoring Wells**. Use of this ASTM standard is acceptable in Yukon. ***Any deviation from the requirements provided in the standard or presented below must be identified, together with supporting rationale.***

3.1 Well Development

Monitoring well development should follow the installation process and continue until the water is representative and free of the drilling fluid cuttings, or other materials introduced during the drilling process. Development is also intended to correct any clogging or compaction that may interfere with water quality analysis, to improve hydraulic characteristics, and to restore groundwater properties disturbed during the drilling process.

Several techniques may be appropriate for well development that may not be suitable for groundwater sampling. These include, for example, the use of a surge block to assist in suspending and removing solids from the well screen, and air lifting to surge and remove water from the well. Caution is advised when air lifting, to control downhole pressures and avoid physical damage to the well, and to take precautions if volatiles may be present in the air discharge.

Where wells have been installed for groundwater quality monitoring, it is important that the well is developed soon after installation. However, well development should not be performed prior to 24 hours after installation to allow the hydration of sealant (e.g., bentonite) and proper setting of bentonite or cement-bentonite grout. Representative water is assumed to have been obtained when water sample pH, temperature, and specific conductance readings have stabilized and the water is virtually clear of suspended solids.

3.2 Sampling Following Development

To reduce uncertainty in the subsequent monitoring data set, it is common practice to acquire samples at least one week following well development. It is recognized that, in some circumstances, near-immediate results are required and that many locations are remote and require long travel times***.*** Where sampling is conducted prior to one week following well installation and development, the deviation must be identified along with supporting rationale, and a subsequent sampling round should be planned.

3.3 Purging

At the time of sampling, groundwater is usually first removed from the well and field measurements are monitored over time prior to sample collection in a process referred to as purging. Field measurements are monitored during purging until stable to infer that groundwater conditions representative of the aquifer are present, and that a representative groundwater sample for chemical analysis can be obtained.

Purging should be conducted using methods such as low-flow purging and sampling (see below) that minimize disturbance at the well screen. As per the above-referenced ASTM standard, purging rates should be used that minimize drawdowns in the well while yielding recovery within reasonable time frame (typically about 0.1 L/minute to 0.5 L/minute).

Conventional purging practice is to remove at least three to five "well volumes" prior to sampling, where a well volume comprises the volume of standing water in the well. Alternatively, purging may be considered complete when one or more indicator parameters have stabilized. Indicator parameters that may be monitored include pH, temperature, specific conductance, turbidity, redox potential, and dissolved oxygen (DO). Stability should be defined by an acceptable range for each parameter prior to initiating purging. As per ASTM, suggested ranges by US EPA are "approximately 10% over two successive measurements made 3 min apart, or ASTM ranges of +/-0.2°C for temperature, +/- 0.1 standard units for pH, +/- 3 % for specific conductance, +/- 10 % for DO, and +/-10 mV for redox potential."

As discussed below, there are conditions in high permeability materials where purging may be unnecessary prior to sample collection. In such cases, rationale and supporting data must be provided to justify the use of no-purge sampling.

3.4 Groundwater Sampling

Sampling Methods

Once conditions in the well are considered stable, then a variety of acceptable sampling methods are available and acceptable to acquire the groundwater sample. Where applicable, low-flow sampling (peristaltic, bladder, centrifugal, or variable speed low-flow electrical submersible) of monitoring wells is usually favoured over conventional procedures (e.g., bailers or inertial lift pumps) because minimized disturbance at the well screen during sampling will also minimize volatilization losses and re-suspension of colloidal materials. The procedure also usually reduces the volume and handling of large volumes of purge water, which must be characterized and handled in accordance with the Environment Act and its regulations. In situations where the well is completed in a low-permeability formation, it may be necessary to purge at very low flow rates (i.e., less than 100 mL/minute), taking care to avoid dewatering of the well screen.

Other approaches, such as no-flow or passive sampling should be considered based on the site-specific conditions. Sampling using such approaches is predicated on the assumption that the natural horizontal groundwater flux across a monitoring well screen is sufficiently high to develop groundwater chemical conditions in the well that are representative of conditions in the adjacent geologic formation. Such an assumption is likely to be valid in permeable formations (e.g., sands and gravels), but may be invalid in less permeable materials where stagnant water may be present in the well. No-flow purging and sampling refers to sampling procedures that negate the need for any purging prior to sample collection. Examples include:

- **Micro-purging**. Only the sample tubing of, for example, a peristaltic pump is purged prior to sample collection.
- **Discrete downhole samplers**. The sampling device is submersed downhole, opened and filled at a discrete depth, and returned to surface for chemical analysis.
- **No purge passive grab samplers**. This refers to a group of sampling devices that are typically composed of elongate semi-permeable membrane bags (often polyethylene plastic), which can be submersed in monitoring wells, allowed to equilibrate, and then withdrawn for chemical analysis. The bag is filled with a liquid (usually distilled water) and inserted to a discrete depth within the well screen of a monitoring well. After allowing a period to achieve

chemical equilibrium across the membrane (usually several days), the bag is retrieved and the liquid analysed for the constituents of concern. Single and multi-interval passive diffusion bags are available.

Filtering Samples in the Field

Where groundwater samples are obtained for quantifying metals concentrations, it is important that the samples be filtered in the field under pressure during or immediately after retrieval, and prior to preserving the sample (e.g., with nitric acid). Typically, a clean 0.45 micrometre membrane filter is employed. The sample should be collected in an acid-cleaned plastic container.

Sampling for Organic Compounds

Groundwater samples collected for analysis of organic constituents must not be field-filtered prior to laboratory analysis. The recommended container for collection is a solvent rinsed, amber coloured glass with an aluminum foil or Teflon liner cap. Volatile Organic Compounds (VOCs) should be the first sample that is collected following the purging process. Samples should be placed directly in glass bottles with no air space left and capped with a Teflon septum cap. Samples for extractable organics should be collected after the VOCs samples.

Analytical Tests

Analytical tests should be selected to address not only the known or suspected contaminants of concern at a site (e.g., the chemical constituents initially released to the subsurface), but also the potential contaminants that may form in the subsurface as a consequence of chemical or biological transformation (e.g., vinyl chloride from trichloroethene), or changes in geochemical conditions (e.g., decreasing redox potential, leading to dissolution of metals). For example, increased concentrations of manganese and other metals in groundwater can often result from the geochemical reduction of metals to their more soluble form, as a consequence of biodegradation of organic substrates such as petroleum hydrocarbons.

In addition to analytical tests associated with the contaminants and their transformation, concentrations of major ions (e.g., sodium, calcium, magnesium, chloride, sulphate, bicarbonate and carbonate) to the extent that they can assist in defining the subsurface groundwater flow regime or contaminant transport and fate.

Sample Preservation

To assist in maintaining the natural chemistry of a sample, it is often necessary to preserve the sample. Methods of sample preservation are relatively limited and are intended to reduce the effects of chemical reactions, the effects of sorption and to arrest biological actions. Preservation methods may vary among laboratories and are generally limited to pH control, refrigeration, and protection from light. Selected parameters or groups of parameters (e.g., metals) may be preserved by addition of a reagent (e.g., acid) that stabilizes their concentration but may preclude the analysis of that sample for other parameters. It is important to discuss preservation requirements and site conditions (e.g., remote locations, ambient temperatures, transport constraints) with the laboratory prior to initiating the field sampling program.

Containers must be kept full until samples are analyzed to maintain anaerobic conditions. The sample container material must be non-reactive with the sample and especially with the particular analytical parameter to be tested. Sample containers used to transport samples to the lab must undergo pre-treatment procedures. Samples must be placed in bottles as quickly as practicable upon collection and, where preservation of the sample is required, it should be carried out immediately.

Handling of the sample and contact with the atmosphere should be kept to a minimum. The samples should be properly packaged so as to prevent breakage and should generally be kept at 4^oC plus/minus 2^oC until analyzed by the laboratory.

Quality Assurance/Quality Control

Data validation and quality assurance/quality control (QA/QC) are important considerations for groundwater investigation programs. Care should be taken to use appropriate and consistent field procedures, and to quantify analytical data using approved methods by an accredited laboratory. Data quality objectives should be established at the beginning of the field program, and the data should be compared against these objectives for completeness of the data set, and to define the approximate level of precision and accuracy for decision-making purposes. Commonly, for groundwater investigation studies at least 10% of the samples or one sample per batch, if less than ten, are obtained in duplicate for assessment of reproducibility.

In addition to field duplicates, it is good practice to ***obtain at least two groundwater samples on different days from any monitoring well*** prior to making decisions based on the chemistry data. Groundwater chemistry may change over time at a particular location as a result, for example, of seasonal changes in flow direction and/or changes to the saturated thickness of the aquifer.

4.0 Well Decommissioning

Monitoring wells that are no longer required for monitoring purposes, wells that are damaged or compromised in any way, where the well's continued existence might constitute a safety hazard, or allow a contaminant to enter the aquifer, shall be properly deactivated and closed by an approved method that is sufficient to prevent the vertical movement of water in the well.

Neglected wells often become damaged and/or buried, and may provide conduits for contamination (e.g., a surface spill at an industrial site) to enter the subsurface. The objectives of successful well deactivation and closure are to prevent surface infiltration of contaminants to an underlying aquifer, and to prevent cross communication between flow zones intercepted by a well screen and monitored interval.

Additional information regarding decommissioning a groundwater monitoring well can be found in ASTM standard **D599-99 Standard Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes and Other Devices for Environmental Activities**. Use of this ASTM standard is acceptable in Yukon. ***Any deviation from the requirements provided in the standard or presented below must be identified, together with supporting rationale.***

The following standard methods for well decommissioning are approved:

1. For single monitoring wells with an intact bentonite seal in the annulus, and which intersect a shallow groundwater table located in surficial deposits/weathered bedrock, the approved decommissioning method is as follows.

a) Remove the casing and cap, or if it cannot be removed, cut it off 0.6 m below the ground surface. Fill the remaining casing (or hole if the casing has been removed) to 0.6 m below the ground surface with bentonite pellets or chips while tamping to prevent bridging of the chips or bentonite. Ensure that the bentonite is saturated to provide an effective seal. Fill the remainder of the casing (or hole if the casing has been removed) with silica sand or overburden material to surface.

2. For any type of monitoring well installation that does not meet the definition in Part 1), or where any of the following conditions exist, use methods (a) and (b) below.

- Installations where groundwater contains chloride concentrations in excess of 10,000 mg/L.
- Multilevel well installations.
- Monitoring wells which may compromise the effectiveness of a low-permeability geological unit that overlies a water-bearing unit.
- Monitoring wells greater than or equal to 150 mm in diameter.
- Monitoring wells lacking an intact bentonite seal in the annulus.

a) For wells where the screen and filter pack intervals do not cross communicate between separate groundwater flow zones then, if possible, the well casing should be pulled, and the resulting borehole backfilled from its base using a tremie pipe to deliver a low permeability grout such as bentonite or a cement-bentonite mixture. If the borehole collapses after casing removal or where long well screens cross communicate between flow zones, then the well must be re-drilled and grouted from its base to surface.

b) As an alternative to well removal, the well may be sealed by injecting grout into the well under pressure, with the intent of injecting grout through the well screen and into the surrounding filter pack. Simple placement of grout into the well casing will not necessarily address the filter pack of the well. It may be necessary to perforate the casing to allow grout to penetrate the well annulus. In situations where the well completion interval is one metre or less, the issue of hydraulic cross communication by the filter pack will be of less concern, and simple sealing of the casing with bentonite to surface may be appropriate.

Where the well is damaged below grade and cannot be accessed, attempts should be made to drill out the well and then grout the borehole to surface. Caution is advised, however, as attempts to over drill piping such as polyvinyl chloride (PVC) can sometimes result in lateral displacement of the pipe into the sidewall.

5.0 Special Considerations

If someone wishes to install, sample or decommission a monitoring well to a different standard than that described above, they must first obtain approval from Environment Yukon’s Standards & Approvals section. Such deviations must be documented in the reports produced for the site.

6.0 Failure to Comply

When a monitoring well installed or decommissioned after the effective date of this protocol fails to meet the requirements described herein, the Standards & Approvals section may reject any data derived from that well.

When groundwater sampling conducted after the effective date of this protocol fails to meet the requirements described herein, the Standards & Approvals section may reject those sample results.

7.0 Effective Date

The effective date of this protocol shall be December 20, 2017, and it shall remain in effect until replaced or rescinded by the Standards & Approvals section.

8.0 Acknowledgements

This document was prepared by Golder Associates Limited.

9.0 Additional Information

For more information on contaminated sites, please contact:

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