DEVELOPMENT PERMIT

NO. **DP- 2016-13**

TO: **Hyak Marine Services**

ADDRESS: **P.O. Box 570**
Gibsons, B.C. V0N 1V0
(Permittee)

1) This Development Permit is issued subject to compliance with all of the Bylaws of the Town of Gibsons applicable thereto, except those specifically varied or supplemented by this Permit.

2) The Development Permit applies to those "lands" within the Town of Gibsons described below:

Parcel Identifier: **007-359-870 and 007-359-829**

Legal Description: **Lot 2, Block A, Plan 14197, District Lot 686 and Lot 1, Block A, Plan 14197, District Lot 686**

Civic Address: **377 and 385 Gower Point Road**

3) These lands are within Development Permit Area of the Town of Gibsons Official Community Plan (Bylaw 985, 2005). This permit applies to the following Development Permit Area:

- Development Permit Area No. 9 (Gibsons Aquifer) for the purpose of the protection of the Gibsons Aquifer.

4) The "land" described herein shall be developed strictly in accordance with the terms and conditions and provisions of this Permit, and any investigations and specifications attached to this Permit which shall form a part thereof, specifically:

- Detailed Site Investigation, prepared by Keystone Environmental Ltd., dated July 7, 2016
- Proposed Drilling Program for "The George" Project, prepared by Keystone Environmental Ltd, dated August 2, 2016
- Borehole Table, Prepared by Keystone Environmental Ltd.

5) All requirements of the site investigation are to be followed. On site monitoring by Keystone Environmental Ltd. during construction as outlined in the site investigation is required.

6) Minor changes to the aforesaid site investigation that do not affect the intent of this Development Permit are permitted only with the approval of the Town of Gibsons and Keystone Environmental Ltd.

7) If the Permittee does not commence the development permitted by this Permit within twenty four months of the date of this Permit, this Permit shall lapse.

8) This Permit is NOT a Building Permit.

ISSUED THIS 2nd DAY OF August, 2016.

Dave Newman
Director of Engineering

Copy of permit to Keystone Environmental Ltd.

Proposed Drilling Program for "The George" Project

Submitted to: The Town of Gibsons

Date Issued: August 2, 2016

Prepared by: Keystone Environmental Ltd.

cc:	Town of Gibsons Representative:	Dave Newman – Director of Engineering
	Drilling Contractor:	Mud Bay Drilling Co. Ltd.
	Vacuum Truck Contractor:	Bonniebrook Industries

Contact List:

EMERGENCY NUMBERS	
Town of Gibsons Representative:	Dave Newman (work 604-886-2274 ext. 212, cell 604-741-8370)
Mud Bay Drilling Representative:	Mike Parkinson (work 604-888-2206, cell 604-788-5528)
Keystone Environmental	Michael Geraghty (604-970-9421)
Ambulance/Hospital:	911

PRIME CONSULTANT IN CHARGE (KEYSTONE ENVIRONMENTAL)	
Project Manager:	Michael Geraghty (work 604-430-0671, cell 604-970-9421)
Field Supervisor:	Christopher Homes (work 604-430-0671, cell 778-233-0655)

TOWN REPRESENTATIVE	
Town Representative:	Dave Newman (work 604-886-2274 ext. 212, cell 604-741-8370)

SERVICE COMPANIES	
Drilling Contractor:	Driller: Ian Taylor (work 604-888-2206, cell 604-880-5181)
Grouting/cement contractor:	Mud Bay Drilling
Vacuum Truck:	Bonniebrook Industries (work 604-886-7064)
Waste Removal Contractor:	N/A
Barge Operator:	N/A

1. OVERVIEW

1.1 Purpose

The purpose of the subject drilling program is to determine is soil contamination at the Site has impacted the shallow groundwater aquifer. The objective is to install four (4) groundwater wells in such a manner as to **not** penetrate the underlying Gibsons Aquifer at the site.

1.2 Aquifer

The proposed drilling area is underlain by a known artesian aquifer (the Gibsons Aquifer, BC Aquifer # 560) and therefore, an increased standard of care is needed to protect the aquifer during investigative work.

Based on the Town of Gibsons Aquifer Mapping study (2013) prepared by Waterline Resources Inc., piezometric heads of over 15 m (50 ft) above sea level are understood to be possible if the aquifer is penetrated. In addition, at Town Well 1, artesian flow in excess of 7.6 L/s (100 Igpm) was noted at the time of drilling.

1.3 Risks

We envisage that the following risks would be involved in the proposed drilling program:

1. Uncontrolled artesian flow if the aquitard is breached and control of the well is lost.
2. Development of a sinkhole if artesian flow is left unattended or site personnel are unprepared to mitigate the flow.
3. Impact on the Town of Gibsons' water wells if the aquifer is breached and left unsealed.
4. Potential loss of aquifer pressure if the aquifer is breached and not sealed properly.

1.4 Proposed Drilling Program

Table 1 summarizes the proposed drilling program with anticipated depth, location, and installation plan for each hole. The proposed borehole locations are shown on Figure 1.

Table 1: Proposed Boreholes

Temporary ID	Proposed Location	Expected Depth	Installation Plan
BH16-A	North of Winn Rd., in the former Storage Tank Area, west of MW04-3 and south of BH04-1. Precise location to be determined on site.	Approximately 4.5 to 6 metres (15 to 20 feet). Hole will be terminated as soon as till-like materials or artesian pressures are encountered.	Install one monitoring well in the upper unconfined aquifer, to the confirmed depth to the top of the confining layer (if present at this location)
BH16-B	North of Winn Rd., between the former office and shop buildings, south of the Winch house. In between SS15-11 and SS15-10. Precise location to be determined on site.	Approximately 4.5 to 6 metres (15 to 20 feet). Hole will be terminated as soon as till-like materials or artesian pressures are encountered.	Install one monitoring well in the upper unconfined aquifer, to the confirmed depth to the top of the confining layer (if present at this location)
BH16-C	North of Winn Rd., in the former Shop Area, in between SS15-19 and SS15-17. Precise location to be determined on site.	Approximately 4.5 to 6 metres (15 to 20 feet). Hole will be terminated as soon as till-like materials or artesian pressures are encountered.	Install one monitoring well in the upper unconfined aquifer, to the confirmed depth to the top of the confining layer (if present at this location)
BH16-D	North of Winn Rd., and north of the former Shop Area, west of MW04-04, in between sample 7 and 17 (by others). Precise location to be determined on site.	Approximately 4.5 to 6 metres (15 to 20 feet). Hole will be terminated as soon as till-like materials or artesian pressures are encountered.	Install one monitoring well in the upper unconfined aquifer, to the confirmed depth to the top of the confining layer (if present at this location)

2. PRE- DRILLING REQUIREMENTS

The following have been established:

1. Knowledge and understanding of BC's Groundwater Protection Regulations.

2. WorkSafe BC program (site specific H&S requirements including traffic control, special considerations).

3. Permit Requirements: We understand that the only permit requirements are from the Town of Gibsons.

4. Driller certification: Training certification documents for the driller that will be conducting the subject drilling program (Ian Taylor) is attached. Certifications for the drillers helpers (Ryan Berg and Brad Mackenzie) are attached.

5. All rig lifting equipment, and overhead equipment will be certified to the Original Equipment Manufacturers Specifications (OEM).

6. Casing running procedures: 4" Core Barrel, drill rods, and 6", 7", and 8" casing to be presented to the drill head by way of "rod/casing handler". This mechanical device allows for the safe connection of the drill string without the added risk of crew members physically holding rods or casing while they turn into the drill head.

7. Certificate of Insurance and WorkSafeBC letters are attached.

8. Drill rig specifications (Sonic DB320) are attached.

3. RIG MOVE, RIG UP, AND SITE SAFETY

The following procedures and site safety provisions will be followed during mobilizing, set up, and operation of the drill rig:

1. Mud Bay to contact Keystone Environmental the day before drilling to confirm that the site and drill are ready.

2. Move in and rig up drilling rig and auxiliary equipment on site. Prior to initiating drilling, carry out detailed rig inspection and report any unsafe conditions to Keystone Environmental.

3. Hold a pre-drilling safety meeting with the rig crew and site personnel and discuss the Hazardous Operations and drilling program.

4. Certified driller from Mud Bay to be on site at all times during drilling.

4. GENERAL SONIC DRILLING PROCEDURES

4.1 Roles and Responsibilities.

1. Mud Bay will operate all drilling and auxiliary equipment, retrieve soil samples, install standpipes, and seal boreholes.

2. Keystone Environmental will carry out utility locate search, indicate possible drilling locations, log stratigraphy, collect representative soil samples and direct monitoring well installation.

3. Keystone Environmental's field hydrogeologist will be on site to supervise monitoring well installation and sealing of test holes, as required, to ensure that there is no adverse impact on the aquifer.

3. Town of Gibsons' may review drilling operations, electrical conductivity data, standpipe installation and hole sealing procedures to ensure that the integrity of the aquifer is maintained.

4.2 Methodology of Data and Sample Collection

1. A field supervisor from Keystone Environmental will be on site to collect select soil samples at regular intervals and at changes of soil condition, or at particular zones of interest. Keystone's field hydrogeologist will be on site to supervise monitoring well installation and sealing of test holes, as required, and to verify that all measures are taken to maintain the integrity of the aquifer.

2. Soil samples will be transported to the analytical laboratory (Maxxam Analytics) for soil analysis.

3. Static head elevations will be estimated if shallow groundwater is encountered.

4.3 Drilling Details

4.3.1 Borehole BH16-A

This proposed borehole will be drilled vertically at the location and to the depth noted in Table 1, which assumes that the top of the aquitard (confining layer, if present) will be encountered between 2.4 and 5.2 metres depth (8 to 17 feet). The actual termination depth of this borehole will be finalized in the field based on observations of cutting samples, borehole advancement rates, EC data, and the presence of confining materials (if present). We plan to terminate the hole as soon as the confining layer or artesian groundwater is observed. The borehole will generally be advanced as follows, as illustrated in the attached "Sonic Drilling System" brochure:

1. Sonically advance core barrel into the undisturbed soil, we will use 1.5 m versus the typical 3.0 m per run (i.e., before retrieving the soil sample), targeting the unconsolidated soils above the confining layer (i.e. the underlying glacial till, where present). Vibration and rotation only will be used to advance the core barrel. The confining layer (glacial till) is expected to be encountered at 4.0 metres (13 feet) depth based on the closest borehole logs.

2. Sonically override a larger diameter casing over the core barrel using water to clear the annulus.

3. Return the core barrel to the surface for sample extraction and logging by Keystone.

4. Complete coring and overriding casing advancement to desired depth.

5. Field Environmental Scientist to complete soil description, logging and collect representative samples and EC data as previously described.

6. Keystone field Hydrogeologist to observe the process and assist wherever possible, as previously described.

7. Between runs, measure water level and collect salinity reading to confirm seawater or fresh water inside casing.

8. If the aquitard soil (understood to be comprised of glacial till), aquifer materials (understood to be comprised of coarse grained sand and/or gravel) and/or artesian pressures are encountered, the hole would be terminated immediately and completed / sealed as described in sections 4.3.5 through 4.3.7 below.

4.3.2 Borehole BH16-B

This proposed borehole will be drilled vertically at the location and to the depth noted in Table 1, which assumes that the top of the aquitard (confining layer, if present) will be encountered between 2.4 and 5.2 metres depth (8 to 17 feet). The actual termination depth of this borehole will be finalized in the field based on observations of cutting samples, borehole advancement rates, EC data, and the presence of confining materials (if present). We plan to terminate the hole as soon as the confining layer or artesian groundwater is observed.

4.3.3 Borehole BH16-C

This proposed borehole will be drilled vertically at the location and to the depth noted in Table 1, which assumes that the top of the aquitard (confining layer, if present) will be encountered between 2.4 and 5.2 metres depth (8 to 17 feet). The actual termination depth of this borehole will be finalized in the field based on observations of cutting samples, borehole advancement rates, EC data, and the presence of confining materials (if present). We plan to terminate the hole as soon as the confining layer or artesian groundwater is observed.

4.3.4 Borehole BH16-D

This proposed borehole will be drilled vertically at the location and to the depth noted in Table 1, which assumes that the top of the aquitard (confining layer, if present) will be encountered between 2.4 and 5.2 metres depth (8 to 17 feet). The actual termination depth of this borehole will be finalized in the field based on observations of cutting samples, borehole advancement rates, EC data, and the presence of confining materials (if present). We plan to terminate the hole as soon as the confining layer or artesian groundwater is observed.

4.3.5 Monitoring Well Installation Details

Monitoring wells are planned to be installed in all four boreholes as follows:

1. Check the observed shallow groundwater level at the completion of the borehole drilling, to ensure an artesian condition is not present (if present see Section 4.3.6).
2. Lower the nominally 50mm diameter PVC screen and riser pipe (PVC slotted screen in lower portion, PVC solid in upper portion) to the bottom of the borehole.
3. With the use of a tremie line, place silica filter sand adjacent to the screened section of the piezometer.
4. Design piezometer installation materials to correlate with the removal of the drill casings (i.e. Install 1.5 m of piezometer material, and then remove 1.5 m of casing).
5. Place a nominally 0.6 m thick bentonite seal above silica sand filter pack using tremie line in same manner as installation of silica sand. Use bentonite coated pellets in the place of chips if necessary.
6. Above the bentonite seal, grout the remaining annular space with a weighted cement grout mix to ensure that the grout seals against the borehole walls.
7. When placing grout (Cement / bentonite mixture) in the annular space, the weight and volume of grout should be calculated to balance any surficial formation water pressure at a depth below the bottom of the steel drill casing, so that the casing can subsequently be removed.
8. The grout (calculated weight and volume) is placed by tremie into the annular space above the bentonite seal to a depth estimated to be below the bottom of the steel drill casing. This drill casing is then retracted to a depth estimated to be above the level of the grout column. Pressure grouting may be required if the above is found to be inadequate.

9. The grout should be brought to a level within 0.3m from surface. The depth to grout shall be measured and monitored to determine if the seals heave during grout set. Allow the grout to set.

10. Upon completion, groundwater should be present in the piezometer, but the well should NOT be artesian, and NO flow should be present in the annular space at the ground surface.

11. The remaining 0.3 m will be used to install a flush-mount wellhead protector, and concrete surface plug.

12. The completed monitoring well will be visually monitored by site personnel (Keystone or the owner's representative) throughout the rest of the day and for subsequent days. Any sign of flow from the borehole would be reported to Keystone immediately, and remedial action would be taken as soon as possible (which may require re-mobilization of drilling equipment to the site).

4.3.6 Borehole Abandonment Program (Flowing Artesian Hole, if Piezometer Not Installed)

If flow artesian conditions are encountered (penetration of the confined aquifer);

1. If artesian conditions are encountered and water is flowing out the top of the casing, short pieces of casing could be added until the water stops flowing or is reduced to a small flow that will allow the placement of bentonite chips and pellets by gravity. A cap would be placed with a pressure gauge onto the top of the casing to determine the artesian pressure before adding supplementary casing lengths. The location of each borehole will be surveyed based on a common datum.

2. Backfill with bentonite chips from the bottom of the borehole to the top of the confining layer (if present). Confirm that artesian flow has stopped prior to proceeding prior to completely pulling the casing.

3. Once artesian flow has stopped, backfill on top of the bentonite chips with a layer of coated bentonite pellets.

4. Mix a recipe of Portland cement and barite as heavy as possible and still be able to pump into the casing from the top of the bentonite pellets to the surface. Take the 'Mud Balance' to measure the weight of the 'heavy cementatious grout' so that we know the pressure of the grout column that is placed to balance any artesian water pressure that may be encountered. We want to place the bentonite to act as a 'plug' into the aquifer. If we did not place this bentonite plug, the cementatious grout may 'disappear' into the aquifer.

5. No casing would be removed prior to confirming control of any artesian flow.

6. Allow cement/bentonite to set and confirm seal before moving off the location.

7. Sufficient volume of fresh water would be on site for the mixing of the cementatious grout.

8. Larger diameter casing will be available to override the 6" casing should the artesian flow through an annular space between the 6" casing and borehole wall.

9. Storage capacity would be available on site for the collection of any drill fluid returned to the surface.

10. The completed hole will be visually monitored by site personnel (Keystone or the owner's representative) throughout the rest of the day and for subsequent days. Any sign of flow from the hole would be reported to Keystone immediately, and remedial action would be taken as soon as possible (which may require re-mobilization of drilling equipment to the site).

4.3.7 Borehole Abandonment Program (Non-Flowing / Non-Artesian Hole, if Piezometer Not Installed)

If the drilled boreholes are to be abandoned without installing a well tube;

1. Backfill with bentonite chips from the bottom of the borehole to form a base plug.
2. Grout the borehole to within 0.3 m (1 ft) of surface.
3. The completed hole will be visually monitored by site personnel (Keystone or the owner's representative) throughout the rest of the day and for subsequent days. Any sign of flow from the hole or heave in the grout seal would be reported to Keystone immediately, and remedial action would be taken as soon as possible (which may require re-mobilization of drilling equipment to the site).
4. Once the well plug is determined to be holding, install a cement plug at surface.

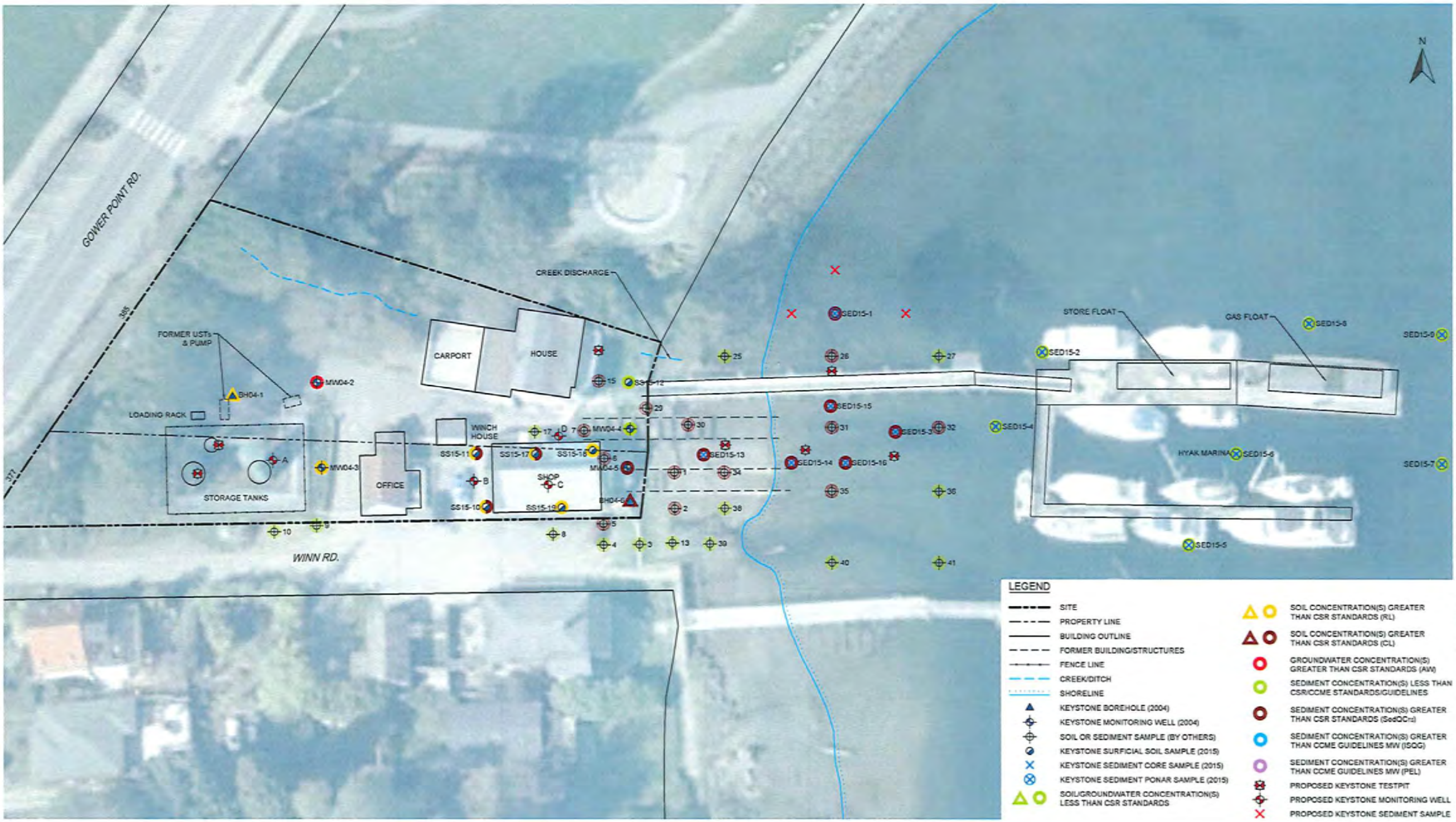
5. FIELD PACKAGE

The following documents are attached:

1. Figure 1: Proposed test hole location plan
2. Sonic Drilling System brochure
3. Mud Bay's Sonic DB320 drill rig specifications sheet
4. Mud Bay drillers' safety training records
5. Mud Bay Drilling's WorkSafe BC letter
6. Keystone Environmental's WorkSafe BC letter
7. Mud Bay Drilling's Certificate of Insurance
8. BC Ministry of Environment "Flowing Artesian Well" document
9. Site Plan

The following signees read this document and understand their responsibilities and agree to implement the requirements of this document.

Name	**Company**	**Position**	**Signature**



Keystone Environmental

NOTES:
1. THIS DRAWING IS FOR GENERAL INFORMATION ONLY. LOT BOUNDARIES AND FEATURES ARE APPROXIMATE.
2. DATE OF AERIAL PHOTO IS 2014.

5m 0 25m

SCALE: 1:500(approx.)

377 & 385 Gower Point Road
Gibsons, B C
Klaus Fuerniss Enterprises Inc.

REVISION No.	DATE	PROJECT No.
01	July 2016	12845-04

Figure 1
Proposed Sample Location Plan

PLOT SCALE: 1:1 DRAWN BY: DK CADD FILE No. 12845\Figs\Proposal\Fig1-Proposal-R1.dwg

SONIC DRILLING SYSTEM

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THE LEADER IN SONIC DRILLING TECHNOLOGY

Whether your drilling needs are for environmental water supply development, geoconstruction, geotechnical or mineral exploration, Sonic drilling technology offers **several distinct advantages** over conventional drilling:

BENEFITS OF SONIC

SUPERIOR INFORMATION

Sonic drilling provides a continuous, relatively undisturbed core sample of unparalleled quality and accuracy through any type of formation. When using the iso-flow groundwater profiling system, hydrogeological and
geochemical data can be easily obtained.

WASTE REDUCTION

Sonic drilling reduces waste by up to 80% relative to conventional methods.

(Amount of waste typical for a 100' installation of a 2" monitoring well.)

SUPERIOR WELL CONSTRUCTION

Sonic drilling causes minimal disturbance to the surrounding borehole wall, resulting in more efficient well development and performance.

SPEED

Sonic drilling is two to three times faster than conventional overburden drilling methods.

RISK MINIMIZATION

Sonic drilling greatly reduces the risk of project failure due to unknown or difficult subsurface conditions. Projects finish on time and on budget. Sonic drilling obtains the lowest total project cost possible.

FLEXIBILITY

Sonic drilling advances a temporary outer casing as the borehole is drilled, allowing you to do more within a single borehole.

OSCILLATOR DIAGRAM

Oscillator Detail

HOW SONIC DRILLING WORKS

Sonic drilling employs the use of high-frequency, resonate energy to advance a core barrel or casing into subsurface formations. During drilling, the resonant energy is transferred down the drill string to the bit face at various Sonic frequencies. Simultaneously rotating the drill string evenly distributes the energy and impact at the bit face.

The resonant energy is generated inside the Sonic head by two counter-rotating weights. A pneumatic isolation system inside the head prevents the resonate energy from transmitting to the drill rig and preferentially directs the energy down the drill string.

The Sonic driller controls the resonant energy generated by the Sonic oscillator to match the formation being encountered to achieve maximum drilling productivity. When the resonant Sonic energy coincides with the natural frequency of the drill string, resonance occurs. This results in the maximum amount of energy being delivered to the face. At the same time, friction of the soil immediately adjacent to the entire drill string is substantially minimized, resulting in very fast penetration rates.

SONIC DRILLING PROCEDURE

SONIC BOREHOLE ADVANCEMENT

The Sonic drilling method advances a casing as the borehole is drilled. While there are several ways to drill a bore hole with the Sonic drilling method (depending upon site-specific conditions and project objectives), the most common means involves advancing a core barrel, which is overridden by a larger diameter drill string that cases the open borehole and prevents collapse.

Typical Sonic drilling procedure:

1. Sonically advance core barrel into the undisturbed formation. No air, mud or water is used in the coring process.
2. Sonically override a larger diameter casing over the core barrel.
3. Return the core barrel to the surface for sample extraction.
4. Complete coring and overriding casing to desired depth.

- Core sizes of 3" through 8" are available.
- Standard borehole sizes of 3" through 12" can be drilled.
- Depths in excess of 600' in a variety of formations and conditions.

WORLDWIDE DRILLING SERVICES

Offices Worldwide:

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AUSTRALIA
Tel: +61 8 9352 9600

LATIN AMERICA
Tel: +56 2 361 6361

We invite you to contact Boart Longyear and learn more about Sonic drilling and how it can assist you in meeting your drilling needs.

www.boartlongyear.com

BOART LONGYEAR™

› Sonic DB320

Sonic DB320

Our DB320 is a compact, lightweight drill rig especially designed for sonic drilling through unconsolidated material. It has been optimised to extract more comprehensive core samples in sand, clay or gravel than is usually possible with traditional soil sampling techniques.

Height:	Mast up	26' (7.92m)
	Mast down	9' 5" (2.86m)
Length:	With Mast	24' (7.32m)
Width:	6' 8" (2.07m) deck width	
Weight:	12,050 kg (26,566 lbs)	
Torque:	240 da N.M.	
Grnd Pressure:	.037 Mpa (5.4 psi)	
Climbing:	60% (30°)	
Sound Level:	<76 dbA @ 10m	
Equipped:	Skid Steer (Bobcat) for support	
	Rotary Safety Guards	
	Rod / Casing Handler	
	SPT Auto-Hammer	

Capable Of:

- Continuous 4" x 6" Sonic Soil Sampling to 50m (164 ft)
- 7" and 8" Core Barrels Available
- Angle Drilling
- Iso-Flow Sampling
- All Geotechnical Testing
  - SPT, Shelby, Vane Testing
  - Deploying CPT

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Kelowna: 3334 Sexsmith Road / Kelowna BC, Canada V1X 7S5 / p. (250) 765.2210 / f. (250) 769.4206

Certificate	Compliance	Certificate #	Issue Date	Expiry Date
CN - CP E Rail Safe	Required	59405	20-Feb-2014	20-Feb-2017
Commercial Vehicles	Optional		22-Jan-2016	22-Jan-2019
CSTS	Required		27-Nov-2012	
Directing Vehicles	Required		22-Feb-2016	22-Feb-2019
Driver Improvement / Defensive Driving	Optional		05-Jan-2015	
Driver's License	Required		07-May-2013	22-May-2018
Fire Safety	Required		12-Jan-2015	12-Jan-2018
First Aid / CPR	Required		07-Jan-2016	07-Jan-2019
Forklift Operator	Required		04-Jan-2016	04-Jan-2019
Ground Disturbance	Required		06-Jan-2016	06-Jan-2019
Hazard Identification and Risk Assesment	Optional		05-Jan-2015	
Hearing Test	Required		06-Jan-2016	06-Jan-2017
Hours of Service	Required		22-Jan-2016	22-Jan-2019
Imperial Oil RRS	Required		04-Jan-2016	04-Jan-2017
LPS AECOM	Optional		11-Mar-2016	11-Mar-2018
LPS Interim	Required		22-Jan-2016	22-Jan-2017
Port Pass	Required		30-Nov-2012	30-Nov-2017
POST	Required		01-Jan-2016	01-Jan-2017
Respirator Fit Testing	Required		06-Jan-2016	06-Jan-2017
Shell Life Saving Rules	Required		04-Jan-2016	04-Jan-2017
Skid Steer Certification	Required		04-Jan-2016	04-Jan-2019
Suncor - Journey to Zero	Required		04-Jan-2016	04-Jan-2017
Transportation Endoresment	Required		08-Jan-2016	08-Jan-2019
Transportation of Dangerous Goods (TDG)	Required		07-Aug-2014	07-Aug-2017
WHMIS	Required		22-Jan-2016	22-Jan-2019
Wildlife Awareness	Optional		25-Jul-2013	25-Jul-2016

Note: This report does NOT include optional certificates that are missing or expired.

Employee Certificate List
Kensil (Ryan) Berg

Certificate	Compliance	Certificate #	Issue Date	Expiry Date
CN - CP E Rail Safe	Required		30-Jul-2013	30-Jul-2016
Commercial Vehicles	Optional		04-Jan-2016	04-Jan-2019
CSTS	Required		03-May-2012	
Directing Vehicles	Required		Missing	
Driver Improvement / Defensive Driving	Required		06-Jan-2016	06-Jan-2021
Driver's License	Required		03-Jan-2014	16-Nov-2018
Fire Safety	Required		04-Jan-2016	04-Jan-2019
First Aid / CPR	Required		07-Jan-2016	07-Jan-2019
Forklift Operator	Required		04-Jan-2016	04-Jan-2019
Ground Disturbance	Required		22-Jan-2016	22-Jan-2019
Hazard Identification and Risk Assesment	Optional		05-Jan-2015	
Hearing Test	Required		06-Jan-2016	06-Jan-2017
Hours of Service	Required		04-Jan-2016	04-Jan-2019
Imperial Oil RRS	Required		04-Jan-2016	04-Jan-2017
LPS AECOM	Optional		11-Mar-2016	11-Mar-2018
LPS Interim	Required		21-Jan-2016	21-Jan-2017
Port Pass	Required		08-Nov-2014	08-Nov-2018
POST	Required		01-Jan-2016	01-Jan-2017
Respirator Fit Testing	Required		06-Jan-2016	06-Jan-2017
Shell Life Saving Rules	Required		04-Jan-2016	04-Jan-2017
Skid Steer Certification	Required		28-May-2014	28-May-2017
Suncor - Journey to Zero	Required		04-Jan-2016	04-Jan-2017
Transportation Endoresment	Required		08-Jan-2016	08-Jan-2019
Transportation of Dangerous Goods (TDG)	Required		22-Aug-2014	22-Aug-2017
WHMIS	Required		06-Jan-2016	06-Jan-2019

Note: This report does NOT include optional certificates that are missing or expired.

Employee Certificate List
Brad Mackenzie

Certificate	Compliance	Certificate #	Issue Date	Expiry Date
CN - CP E Rail Safe	**Required**		**26-Mar-2014**	**26-Mar-2017**
Commercial Vehicles	Optional		04-Jan-2016	04-Jan-2019
CSTS	**Required**		**12-Jul-2013**	
Directing Vehicles	**Required**		**Missing**	
Driver Improvement / Defensive Driving	**Required**		**05-Jan-2015**	
Driver's License	**Required**		**23-Oct-2013**	**20-Aug-2016**
Fire Safety	**Required**		**04-Jan-2016**	**04-Jan-2019**
First Aid / CPR	**Required**		**07-Jan-2016**	**07-Jan-2019**
Fit Test SCBA	Optional		03-Mar-2016	03-Mar-2017
Forklift Operator	**Required**		**04-Jan-2016**	**04-Jan-2019**
Ground Disturbance	**Required**		**26-Mar-2014**	**26-Mar-2017**
Hazard Identification and Risk Assesment	Optional		05-Jan-2015	
Hearing Test	**Required**		**06-Jan-2016**	**06-Jan-2017**
Hours of Service	**Required**		**04-Jan-2016**	**04-Jan-2019**
Hydrogen Sulfide (H2S)	Optional	000083 Temp	23-Jun-2015	23-Jun-2018
Imperial Oil RRS	**Required**		**04-Jan-2016**	**04-Jan-2017**
LPS Interim	**Required**		**06-Jan-2016**	**06-Jan-2017**
OSSA/BSO	Optional		25-Jun-2015	
Port Pass	**Required**		**10-Dec-2013**	**10-Dec-2018**
POST	**Required**		**01-Jan-2016**	**01-Jan-2017**
Respirator Fit Testing	**Required**		**06-Jan-2016**	**06-Jan-2017**
Shell Life Saving Rules	**Required**		**04-Jan-2016**	**04-Jan-2017**
Skid Steer Certification	**Required**		**28-Apr-2014**	**28-Apr-2017**
Suncor - Journey to Zero	**Required**		**04-Jan-2016**	**04-Jan-2017**
Transportation Endoresment	**Required**		**08-Jan-2016**	**08-Jan-2019**
Transportation of Dangerous Goods (TDG)	**Required**		**06-Jan-2015**	**06-Jan-2018**
WHMIS	**Required**		**04-Jan-2016**	**04-Jan-2019**
Wildlife Awareness	Optional		07-Jul-2015	

Note: This report does NOT include optional certificates that are missing or expired.

WORK SAFE BC
WORKING TO MAKE A DIFFERENCE

Assessment Department
Mailing Address
PO Box 5350
Station Terminal
Vancouver BC V6B 5L5

Location
6951 Westminster Highway
Richmond BC
V7C 1C6
www.worksafebc.com

Clearance Section
Telephone 604 244 6380
Toll Free within Canada
1 888 922 2768
Fax 604 244 6390

Keystone Environmental Ltd
Suite 320
4400 Dominion Street
BURNABY, BC V5G 4G3

July 06, 2016

Person/Business : MUD BAY DRILLING (2015) LTD.
MUD BAY DRILLING
957885 AQ(014)

We confirm that the above-mentioned account is currently active and in good standing.

This firm has had continuous coverage with us since October 01, 2015 and has satisfied assessment remittance requirements to April 01, 2016.

The next payment that will affect this firm's clearance status is due on July 20, 2016.

This information is only provided for the purposes of Section 51 of the *Workers Compensation Act*, which indicates that a person using a contractor or subcontractor to perform work may be responsible for unpaid assessments of the contractor or subcontractor.

Employer Service Centre
Assessment Department

Clearance Reference # : C129024863
CLRA1A

WORK SAFE BC
WORKING TO MAKE A DIFFERENCE

Assessment Department
Mailing Address
PO Box 5350
Station Terminal
Vancouver BC V6B 5L5

Location
6951 Westminster Highway
Richmond BC
V7C 1C6
www.worksafebc.com

Clearance Section
Telephone 604 244 6380
Toll Free within Canada
1 888 922 2768
Fax 604 244 6390

KEYSTONE ENVIRONMENTAL LTD.
320-4400 DOMINION STREET
BURNABY, BC V5G 4G3

July 20, 2016

Person/Business : KEYSTONE ENVIRONMENTAL LTD
488241 AQ(017)

This letter provides clearance information for the purposes of Section 51 of the Workers Compensation Act.

We confirm that the above-referenced firm is active, in good standing, and has met WorkSafeBC's criteria for advance clearance. Accordingly, if the addressee on this letter is the prime contractor, the addressee will not be held liable for the amount of any assessment payable for work undertaken by the above-referenced firm to October 01, 2016.

This firm has had continuous coverage with us since July 19, 1993.

Employer Service Centre
Assessment Department

Clearance Reference # : C129056068
CLRAAA

For more information about Section 51 and clearance letters visit WorkSafeBC.com

Please refer to your account number in your correspondence or when contacting the Assessment Department
To alter this document constitutes fraud.

CERTIFICATE OF INSURANCE

DATE (YY/MM/DD) July 29, 2016

BROKER	
envision INSURANCE	This certificate is issued as a matter of information only and confers no rights upon the certificate holder. This certificate does not amend, extend or alter the coverage afforded by the policies below.
	COMPANIES AFFORDING COVERAGE
	COMPANY A — **Intact Insurance Company**
INSURED **Mud Bay Drilling (2015) Ltd.** **19545 Telegraph Trail** **Surrey, British Columbia V4N 4G9**	COMPANY B — **Chubb Insurance Company**
	COMPANY C
	COMPANY D

COVERAGES

This is to certify that the policies of insurance listed below have been issued to the insured named above for the policy period indicated, notwithstanding any requirement, term or condition of any contract or other document with respect to which this certificate may be issued or may pertain, the insurance afforded by the policies described herein is subject to all the terms, exclusions and conditions of such policies.

LIMITS SHOWN MAY HAVE BEEN REDUCED BY PAID CLAIMS.

CO LTR	TYPE OF INSURANCE	POLICY NUMBER	POLICY EFFECTIVE DATE (YY/MM/DD)	POLICY EXPIRY DATE (YY/MM/DD)	LIMITS	
A	GENERAL LIABILITY ☒ COMMERCIAL GENERAL LIABILITY ☐ CLAIMS MADE ☒ OCCURRENCE ☒ TENANT'S LEGAL LIABILITY CROSS LIABILITY INCLUDED EMPLOYERS LIABILITY INCLUDED PRIMARY/NONCONTRIBUTORY COVERAGE XCU COVERAGE INCLUDED ☒ NON-OWNED ☐ HIRED	5A1197508	2015/09/24	2016/09/24	EACH OCCURRENCE	$10,000,000.
					GENERAL AGGREGATE	$10,000,000.
					PRODUCTS – COMPLETED/OP AGG	$10,000,000.
					PERSONAL INJURY	$10,000,000.
					TENANT'S LEGAL LIABILITY	$500,000.
					MEDICAL PAYMENTS ANY ONE PERSON	$2,500.
					NON-OWNED AUTOMOBILE	$10,000,000.
					AGGREGATE	
A	CONTRACTORS EQUIPMENT	5A1197508	2015/09/24	2016/09/24	BROAD FORM	$3,000,000.
B	ENVIRONMENTAL LIABILITY	37334702	2015/10/02	2018/10/02	POLLUTION LIABILITY	$5,000,000.

	ADDITIONAL INSURED	DESCRIPTION OF OPERATIONS/LOCATIONS/AUTOMOBILES/SPECIAL ITEMS
A	Keystone Environmental Ltd. Town of Gibsons	**Drilling Investigation** **Intact Insurance A.M. Best Rating = A+**

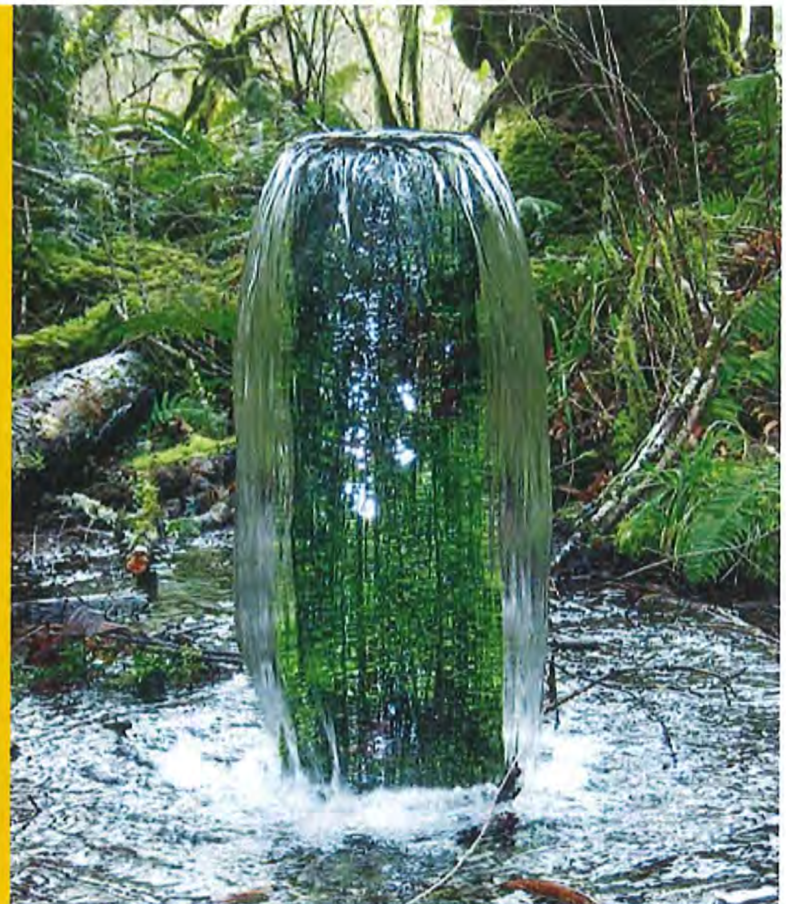
CERTIFICATE HOLDER	CANCELLATION
Keystone Environmental Ltd. Suite 320, 4400 Dominion Street, Burnaby, BC V5G 4G3 Town of Gibsons 474 South Fletcher Road, Box 340 Gibsons, BC V0N 1V0	Should any of the above described policies be cancelled before the expiration date thereof, the issuing company will endeavor to mail **30 days written notice** to the certificate holder named to the left, but failure to mail such notice shall impose no obligation or liability of any kind upon the company, its agents or representatives. AUTHORIZED REPRESENTATIVE – Elaine Stewart, CIP Elaine Stewart Per Envision Insurance Services a division of First West Insurance Services Ltd.

This policy contains a clause that may limit the amount payable.

Flowing Artesian Wells

Water Stewardship Information Series

BRITISH COLUMBIA
The Best Place on Earth



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This booklet contains general information on flowing artesian wells for well drillers, groundwater consultants and well owners in British Columbia. The booklet provides general guidelines on flowing artesian wells and does not replace professional knowledge or experience.

What's the difference between a flowing artesian well and an artesian well?

An **artesian well** is a well that taps into a confined aquifer (see Figure 1). Under artesian pressure, water in the well rises above the top of the aquifer, but does not necessarily reach the land surface. A **flowing artesian well** is one that has been drilled into an aquifer where the pressure within the aquifer forces the groundwater to rise above the land surface naturally without using a pump. Flowing artesian wells can flow on an intermittent or continuous basis and originate from aquifers occurring in either unconsolidated materials such as sand and gravels or bedrock, at depths ranging from a few meters to several thousand meters. All flowing wells are artesian, but not all artesian wells are flowing wells.

Why do wells flow?

Flowing artesian wells can be found in two types of situations:

- the aquifer is confined by impermeable materials (i.e., confined beds where the static water level is above the top of the aquifer and land surface); or
- the aquifer is not confined, but the static water level is above the land surface.

> **Static water level** is the level to which water will naturally rise in a well without pumping. For flowing artesian wells, the groundwater level or static water level can be expressed as a head (e.g., artesian head) and reported as a length (feet or meters above ground level) or pressure (pounds per square inch or psi).

Artesian conditions can be generated by geological and topographical controls (see Figure 1) or by topographical controls alone (Figure 2). In the former, water in an artesian well rises upward due to the pressure confined in the aquifer. Artesian wells are found in inclined confined aquifers sandwiched between layers of rock or overburden that are impervious or have low permeability. Water enters the exposed portion of the aquifer at a high elevation and percolates down through interconnected pore spaces. The water held in these spaces is under pressure (confining pressure or hydrostatic head) due to the high elevation from which it originally came. If a well is drilled from the land surface through the overlying impervious layer, the pressure inside the aquifer will cause the water to rise in the well. In areas where the pressure of the aquifer is great enough, the water rises above ground level resulting in a flowing artesian well.

> **Hydrostatic head** (or confining pressure) is the vertical distance between the water level in the well and the top of the aquifer and is expressed in feet or meters of water or pressure (psi).

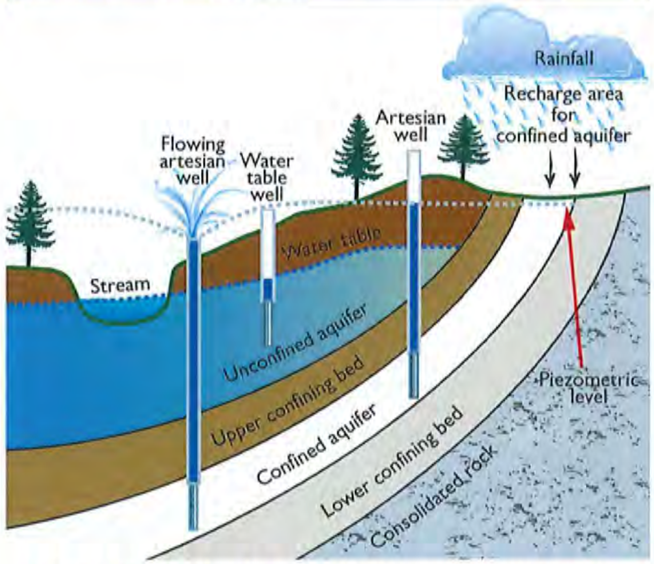

Figure 1. Geological and topographical controls affecting artesian and flowing artesian wells.

Topographical control situations can be found in unconfined aquifers where the well intake is deep enough to intercept a zone where the hydraulic head is higher than the land surface (see Figure 2). This situation typically occurs in groundwater discharge areas at lower elevations near rivers and lakes in valleys surrounded by steep slopes. The pressure of the groundwater typically increases with depth in the discharge areas where the slope of the water's flow path and its pressure are controlled by the topography. As the groundwater moves along the flow path, it can migrate

> **Hydraulic head** is a measurement of the water level or total energy per unit weight above a datum such as sea level. It is commonly measured as water surface elevation in feet or meters.

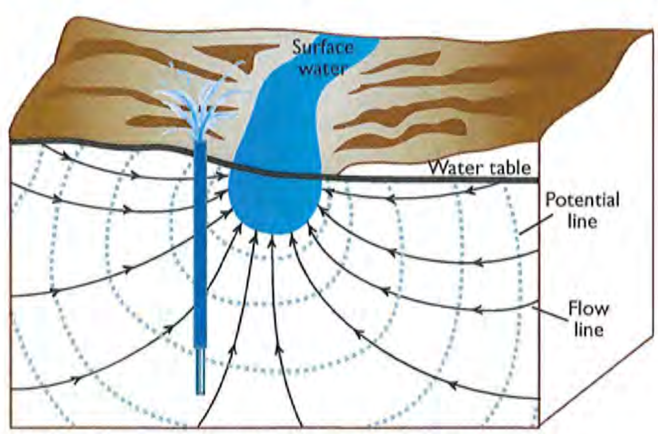

Figure 2. Topographically controlled flowing artesian well.

deep below ground where it can lie beneath shallow non-artesian groundwater. When a well is drilled into a deeper zone of higher hydraulic head, the groundwater can move upwards inside the well casing to a level that is higher than the levels of the land surface, resulting in a flowing artesian well.

Why is stopping or controlling artesian flow important?

Flow from artesian wells should be controlled to prevent wasting groundwater. For instance, an uncontrolled artesian well flowing at 10 USgpm (55 m^3/day) wastes 14,400 USgallons (55 m^3) every day and 5.25 million USgallons (2.0×10^4 m^3) per year. An uncontrolled flow of 1 USgpm wastes enough water to supply four homes. Wasting water may lower the confining pressure in the aquifer so that the well no longer flows or flows at a reduced rate and affects the yield of neighbouring wells and springs.

Figure 3. Erosion caused by flowing artesian well.

When groundwater breaks out on the outside of the well casing, flooding, damage and/or subsidence and sinkhole formation can occur. Another reason to control flow is to prevent groundwater flowing from an aquifer under artesian pressure into an overlying aquifer(s). If the flowing well breakout is not promptly contained, silt, clay, gravel, sand, and drilling fluids can be carried along with the artesian groundwater to the ground surface and eventually reach surface water. The quality of the surface water and the habitat of aquatic organisms can be impacted.

Flowing artesian wells can also cause erosion (see Figure 3). Flowing water that accumulates into ponds can also contribute to mosquito problems.

How can flowing artesian conditions be determined before drilling?

Before a well is drilled, it is important for the person responsible for drilling the well (qualified well driller or qualified professional[1]) to do a pre-drilling assessment to determine the range of pressures and flows that might be found during drilling, i.e., whether flowing artesian conditions are likely to be encountered.

[1] Qualified professionals who are registered with the Association of Professional Engineers and Geoscientists of British Columbia with competency in hydrogeology or geotechnical engineering.

The pre-drilling assessment should include gathering information about geological conditions, static water levels and any history of flowing artesian wells in the area. This information can be obtained from:

- reviewing available local well construction reports;
- reviewing hydrogeologic information (e.g., maps on the Water Resource Atlas http://www.env.gov.bc.ca/wsd/data_searches/wrbc/index.html showing flowing artesian well coverage (see Figure 4) or reports on Ecocat http://www.env.gov.bc.ca/ecocat/);
- consulting with the Ministry of Environment regional hydrogeologists; and
- consulting with well drillers and professional hydrogeologists or geotechnical engineers with knowledge of the local area.

If this information is not available, the person responsible for drilling the well should consider the proposed well depth in relation to relevant topographic and geologic information about the site (i.e., whether the proposed well is going to be deep in a valley-bottom location). Geophysical logs or an electric survey can also be used to better understand subsurface conditions. When knowledge is limited, a precautionary approach should be taken and planning should assume that flowing artesian conditions will be present.

Figure 4. Map from the BC Water Resource Atlas showing provincial mapped and classified aquifers, contoured elevations and wells (purple dots) that were flowing artesian wells at the time drilling.

What are the provincial regulatory requirements for controlling or stopping artesian flow?

The provincial regulatory requirements for controlling flowing artesian wells are outlined in section 77 of the *Water Act*. If artesian conditions are encountered when constructing or supervising construction of a well, the qualified well driller or qualified professional must ensure the artesian flow is or will be stopped or controlled and advise the well owner (and the land owner, if applicable) of the steps taken to do so. It is also good practice to advise of any potential hazards associated with uncontrolled flow not being controlled (e.g., erosion, flooding, subsidence) and any associated costs. Agreement on these issues, prior to drilling can help prevent or minimize misunderstandings. For example, some issues can be addressed in a contract. If the qualified well driller or qualified professional fails to stop or control the flow, it is the well owner's responsibility to hire another qualified professional or qualified well driller to ensure that the flow is stopped or controlled. If the ownership of the well is not known, the land owner is responsible to have this done. If the flow cannot be controlled, the person responsible for drilling the well should advise the Ministry of Environment's regional hydrogeologist and must comply with any direction given.

A flowing artesian well must have a securely attached cap to provide access to the well, prevent entry of vermin and contaminants, and to prevent flow escaping from the well.

What does it mean to "control" artesian flow from a well?

A flowing artesian well is considered "under control" when the entire flow is through the production casing to the wellhead and the flow can be stopped indefinitely without leaking on the surface of the ground and with no leakage into any other aquifer penetrated by the well.

Will a flowing artesian well dry up if the flow is stopped or controlled?

Controlling the flow from a flowing artesian well should not stop the flow or dry up the well if the well has been properly constructed. In fact, the opposite is true as waste of artesian water will often eventually cause a decrease in artesian pressure. Controlling the flow from a flowing artesian well prevents unnecessary loss of groundwater from the aquifer upon which other wells rely.

Are there any water quality concerns with flowing artesian wells?

In general, the water quality of flowing artesian wells is excellent. However, some artesian waters may be very poor quality and cause serious damage on the surface or contaminate an overlaying aquifer. In general, water quality can be affected by the depth of the well, i.e., a deeper flowing artesian well may have poorer water quality than a shallower flowing well. Water from bedrock formations, such as deep sandstone formations, may contain concentrations of arsenic that could pose a health concern. Artesian wells with poor quality water should be permanently closed (see page 8).

Are there any other concerns with flowing artesian wells?

Most of the problems associated with flowing artesian wells result from improper discharge controls or improper well construction.

Casing corrosion (see Figure 5) and leakage can occur due to the constant flow of water, particularly if the water is corrosive

Figure 5. Corroded well casing.

or contains fine sand. Where artesian water is known to be corrosive, a smaller diameter flow pipe may be installed in the well. The pipe may be made of corrosion-resistant material or may be periodically replaced when it becomes corroded. Where the casing has been damaged, a slightly smaller diameter casing can be installed inside the old casing using packers if there is an existing surface seal and sealed in place with a cement grout. It is recommended to have the flowing artesian well checked periodically by a qualified well driller to verify the integrity of the well casing and to inspect the well screen, as the well can be difficult to repair once the casing has been corroded or breached. Thin-wall casing should not be used in flowing artesian wells.

Failure of the casing/surface seal during construction or decades after well completion can be costly and may result in the eruption of large volumes of silt, sand, clay or gravel, causing unstable conditions and potential flooding, damage to nearby structures through erosion and subsidence and harm to the habitat of aquatic organisms.

Well screens for flowing artesian wells can yield water with sand or become plugged with sand if the well is not properly developed. This is an issue when a flowing artesian well in a fine-grained aquifer is shut off and the sand settles and clogs the area in and around the bottom of the casing. The screen size should be coarse enough to prevent pressure build-up in the aquifer and the well should be properly developed. Perforated casings for flowing artesian wells are not recommended. In some areas an unpleasant rotten egg smell (hydrogen sulphide gas) may be present and by reducing or stopping the artesian flow the smell can be brought under control.

What can be done with an existing flowing well?

Trying to stop or control the flow from older flowing wells may result in an uncontrolled discharge of water outside the well casing or at a distance from the well due to the lack of an adequate seal, a defective surface seal or corroded casings. If water does not appear to be flowing outside of the outer casing, then it may be advisable to leave the well alone and not restrict the flow. However, if water appears to be flowing outside the casing and/or the well is causing property or environmental damage, then the well should likely be closed. Alternatively, it may be possible to lower the water levels using a pump but care must be taken to keep the water flowing from the well relatively continuously to avoid additional uncontrolled discharge from occurring.

There are numerous special measures that may be applicable to controlling the flow of an existing flowing artesian well such as using well packers or a bridge to restrict the flow in the confining layer, adding polymers or plasticizers to keep the grout together during placement, using barite to reduce the confining pressure of the water, etc.

Any alteration to an existing flowing well to control the flow needs to be done in compliance with the *Water Act* and Ground Water Protection Regulation and any directions of a Ministry of Environment hydrogeologist. A qualified well driller or qualified professional must be hired. Before any work is done, the well owner should be made aware of the costs and complexities of the work involved with controlling the flowing artesian well, as well as the chances of successfully controlling the flow.

What if the flow is needed, for example, to increase the baseflow of a creek or stream?

In some instances, artesian flow is used to maintain water levels in ponds used for irrigation, fire protection, fish rearing, recreation or wetland enhancement. For existing wells, flow is permissible as long as property is not damaged and streams or aquatic habitats are not negatively impacted. If damage does or may occur, contact the local Ministry of Environment office (see back cover of this booklet).

Are there some general guidelines for constructing a flowing artesian well?

In constructing a well under flowing artesian conditions the potential pressure and flow and the permeability of the formation need to be taken into consideration. A pre-drilling assessment of local conditions may provide this information. If these conditions are known, the following provides general guidance for the design and construction of the well. If this information is not known the well should be designed conservatively for worse case conditions. Flowing artesian wells should not be constructed if the formation conditions are not favourable, i.e., in shallower situations where there is no suitable formation to seal into.

Green Zone (<5 psi)

If the pressure is or will be less than 5 psi (pounds per square inch), flow can usually be controlled by adding additional casing, except where permeability of the formation is extremely high, e.g., medium to coarse gravel. To determine the artesian head use the following conversion factors: 2.31 feet equals 1 psi, and one foot equals 0.3048 meters. For example, for a flowing well with 5 psi, there will be 11.6 ft or 3.5 meters of artesian head, therefore the casing would need to be extended more than 3.5 meters above the ground surface to contain all the artesian head. In general, a 30 per cent bentonite grout can be used for flowing well construction or repair.

Artesian head is the hydraulic pressure created within the confined aquifer that drives the water upward in a well to the piezometric level. The distance from the ground surface to the piezometric level, converted into equivalent pressure (expressed as pounds per square inch, or PSI), is the artesian head.

Yellow Zone (5 to 10 psi)

If the pressure is or will be between 5 and 10 psi, extending the well casing may reduce flow, but extreme care must be taken in highly permeable formations that produce significant volumes of water. Flows of 20 USgpm can potentially occur in this zone and the upward annular velocity resulting from this flow is high enough to begin separating grout mixtures as they are being pumped down. When the pressure is high and the formation highly permeable, it is recommended that an outer surface casing be installed before the permanent casing. The outer casing should end in the confining layer and should not penetrate the underlying artesian aquifer. Cement-type grout should be used.

Red Zone (>10 psi)

If the pressure is or will be greater than 10 psi, static head control or extending the well casing is not usually possible, especially in highly permeable, high-yielding formations. In this category the flow is great enough to make the grout placement very difficult. An outer casing or multiple casings should be installed before the production casing and set to the confining layer so the production casing can be cemented within the outer casing. Cement or cement plus barite (or other weighting additives) should be used as grouting materials.

What are the key issues to be aware of when drilling a flowing artesian well?

Flowing artesian wells under high pressure and with high flow rates (yellow and red zones) are challenging to construct. Flowing wells that are drilled deep (≥200 feet or ≥60 meters) in unconsolidated deposits or drilled into bedrock are less prone to flow problems and are generally easier to deal with. In bedrock environments (see page 7 for more information on bedrock wells), the competent rock allows for easier installation of the seal (i.e., no casing to wash out or concerns about an eroded annulus).

Drilling a well into a confined aquifer disturbs the overlying geologic confining layer and provides a potential pathway for the upward movement of the pressurized artesian water. Well construction must include restoring any damage to the confining layer. In general, the closer the top of the artesian formation is to the ground surface and the higher the pressure, the more difficult it is to control the flow.

In certain conditions (e.g., soft clay/silt formations), the formation will squeeze back in and set up around the well casing over a period of time. If this condition is likely to occur, it is advisable to let the well flow for a week or two to give the formation a chance to settle in before stopping or controlling the flow. This will result in a seal around the casing at deeper depths than the surface seal.

It is good practice for the qualified well driller to observe the condition of the flowing artesian well head for one or two weeks after construction and check for leakages outside the surface casing or between casings.

Materials and Equipment

One of the key factors to successfully controlling the flow is being prepared with the right tools and materials at the job site. Suggested materials and equipment include:

- drilling mud and additives of sufficient weight to deal with the pressures in the aquifer,
- surface and production casing appropriate to the water quality and geological conditions,
- grouting and sealing materials appropriate to the artesian pressure and anticipated flow,
- tremmie pipes,
- pumps suitable for delivering the grouting and sealing materials,
- well screens with adequate transmitting capacity,
- valves,
- inflatable packers,
- surge block, and
- shale traps.

Drilling Muds

To determine the extra weight of drilling mud needed to counteract the pressures of the artesian aquifer during rotary drilling, the estimated artesian head and the depth to the top of the aquifer is needed. The following formula can be used to estimate the additional weight of drilling mud needed to control the flow during the drilling process:

$$\text{Additional mud weight} = \left(\frac{8.34\ \text{lbs/USgal} \times \text{height of water above ground level (ft)}}{\text{Depth to top of aquifer (ft)}}\right) + 0.4\ \text{lbs/USgal}$$

Where:
One USgallon of water weighs 8.34 pounds
0.4 lbs/USgallon is a safety factor

Example

If the depth to the top of the aquifer is 75 feet and the height of water above ground is estimated to be 10 feet, the additional weight of drilling mud needed would be $(8.34 \times 10/75) + 0.4 = 1.5$ lbs/USgal.

Properly mixed, fresh drilling mud will normally weigh about 9 pounds per US gallon. Drilling mud can be made heavier by adding drilling clay, drilling gel and special solids such as barite. However, some drilling gels are treated with polymers to build viscosity and become difficult to pump before their weight significantly increases. Therefore, some drilling gels have limited ability for control of flows. Mud weights of up to 15 pounds per gallon can be achieved using weighting materials such as powdered barite.

Well Casings

Generally, in areas where flowing artesian conditions are known or suspected, at least one outer surface casing should be installed before installing the permanent/production casing or liner to allow for better control. It is not advisable to pull the surface casing within 20 feet (6 meters) of ground surface. Doing so may disturb the seals and cause water to flow around the surface casing as it is pulled, especially if bentonite is used. There should be at least a 4-inch (10 cm) gap or annulus between the outer surface casing and the production casing to allow for the insertion of a tremmie pipe to pump adequate grout volumes For example, if a 6-inch production casing is needed, a 14-inch outer surface casing would have to be installed to provide a 4-inch annulus.

In areas where the pressure is > 5 psi and the formation is highly permeable, a 4 to 6-inch (10 to 15 cm) annulus between the surface and permanent casing is recommended. Ensuring there is an adequate annulus is especially important where formations are highly permeable and high-density grout mixtures are required to adequately control the artesian flow.

Grouting Mixtures

Use of appropriate grouting material is key to constructing a flowing artesian well. Table 1 is useful for finding the hydrostatic head pressure (in psi) and for understanding the relationship between drilling fluid or grout density and their ability to successfully control the flow during drilling, plugging, or repair. Table 1 shows that heavy grouts, such as neat cement/ bentonite slurry or cement slurry with additives, have a distinct advantage for flowing well work. Mixing neat cement with bentonite is recommended to avoid cracks from occurring.

It is important to allow for sufficient time for the cement or cement grout mixture to set before proceeding with drilling. Use of the appropriate drilling method to minimize impacting the integrity of the seal is also important. In addition, the flowing artesian well should be gradually sealed or shut-in to prevent rupturing the seal(s).

TABLE 1
TOTAL PRESSURE ABOVE TOP OF CONFINED AQUIFER (HYDROSTATIC PRESSURE) FOR FLOWING ARTESIAN WELLS

Depth to Top of Flowing Aquifer (feet)	Artesian Head Above Ground Surface (feet)					
	5	10	15	20	25	30
10	6.5	8.7	10.8	13.0	15.2	17.3
20	10.8	13.0	15.2	17.3	19.5	21.7
30	15.2	17.3	19.5	21.7	23.8	26.0
40	19.5	21.6	23.8	26.0	28.1	30.3
50	23.8	26.0	28.1	30.3	32.5	34.6
75	34.6	36.8	39.0	41.1	43.3	45.5
100	45.5	47.6	50.0	52.0	54.1	56.3
125	56.3	58.4	60.6	62.8	65.0	67.1
150	67.1	69.3	71.4	73.6	75.8	78.0
175	78.0	80.1	82.3	84.4	86.6	88.7
200	88.7	91.0	93.1	95.2	97.4	99.6
225	99.6	101.7	104.0	106.0	108.2	110.4
250	110.4	112.5	115.7	117.0	119.0	121.2

Adapted from the Michigan Department of Environmental Quality, Water Bureau, Lansing, Michigan

Material	Weight	Hydrostatic Pressure
Barite Slurry:	18 - 22 lb/USgal	.96 - 1.1 psi/ft
Neat Cement and Bentonite @ 6 gal water/sack:	15.0 lb/USgal	.78 psi/ft
Bentonite Slurry Grout:	10.4 lb/USgal	.54 psi/ft
Bentonite Slurry Grout:	9.5 lb/USgal	.49 psi/ft

GROUTING MATERIAL SUITABILITY

	Heavy Enough To Overcome Hydrostatic Pressure	Not Heavy Enough To Overcome Hydrostatic Pressure
(dark shading)	Neat Cement @ 15 lb/USgal	All Bentonite Grouts
(light shading)	Neat Cement @ 15 lb/USgal or Bentonite Grout @ 10.4 lb/USgal	Bentonite Grouts lighter than 10.4 lb/USgal
(no shading)	All standard grouts have enough weight to overcome hydrostatic pressure of the flow.	

The values in Table 1 correspond to the downhole head pressure (in psi) for different scenarios, e.g., if the depth to the top of the aquifer was 10 feet and the artesian head was 5 feet, the downhole head pressure will be 15 feet or 6.5 psi. To overcome the flow, the downhole grout pressure must be greater than the downhole head pressure.

The following example illustrates how Table 1 can be used to select drilling fluids or grout that are heavy enough to control the flow during drilling.

Example of how to use Table 1

Q. *The top of an artesian aquifer is found at 50 feet and wells in the area have about 15 feet of artesian head. What minimum weight drilling fluid would be needed to overcome the hydrostatic pressure during drilling?*

A. The following steps are used to solve the problem:

Step A: To determine the downhole hydrostatic head pressure look at **Table 1** and find the cell corresponding to depth of top of aquifer (50 ft) and artesian head (15 ft) which is 28.1 psi. This pressure represents the total head above the top of the confined aquifer (e.g., 15 + 50 = 65 ft or 28.1 psi).

Step B: Divide the downhole hydrostatic pressure (28.1 psi) by the depth to the top of the aquifer (50 ft) to determine the downhole grout pressure needed to equalize the flow (28.1 psi/50 ft = 0.56 psi/ft).

Step C: To determine the grout weight divide the downward pressure of the grout (0.56 psi/ft) by 0.052 (a factor to convert lb/USgal to psi/ft of depth). The minimum grout weight needed to control the flow is 10.8 lb/USgal.

Are there specific actions to avoid when flowing artesian conditions are present?

When a large volume, high pressure flow breaks out, the immediate situation can be serious and there is usually a concern to quickly move the drilling rig away from the borehole. Hastily made decisions can get in the way of successful future corrective actions. As up-flowing artesian water typically will erode fine sediments around a solid object that has been placed loosely below ground, the following actions should be avoided:

- dumping field stone or gravel into the annulus around the well casing as this can prevent the installation of grout pipes or a larger casing into the borehole and can collapse PVC well casing;
- pouring ready-mix concrete or bentonite chips into the annulus as it is likely that the concrete or bentonite will solidify above the depth where the flow is originating and

result in a plug that causes the flow to wash out around its perimeter; or

- jamming unopened bags of cement, bentonite chips, lumber, cardboard or other debris into the washed out annulus as these materials are ineffective and complicate further corrective action.

How can flowing artesian wells be constructed in bedrock aquifers?

When constructing an artesian well that is likely to flow in a **bedrock aquifer**, the final or outer well casing should be sealed at least 10 feet (0.3 meters) into competent bedrock. Figure 6 shows one possible method of completing a flowing artesian well in bedrock. Construction techniques and choice of sealant materials need to be determined by the qualified well driller based on site specific conditions, e.g., pressure and flow.

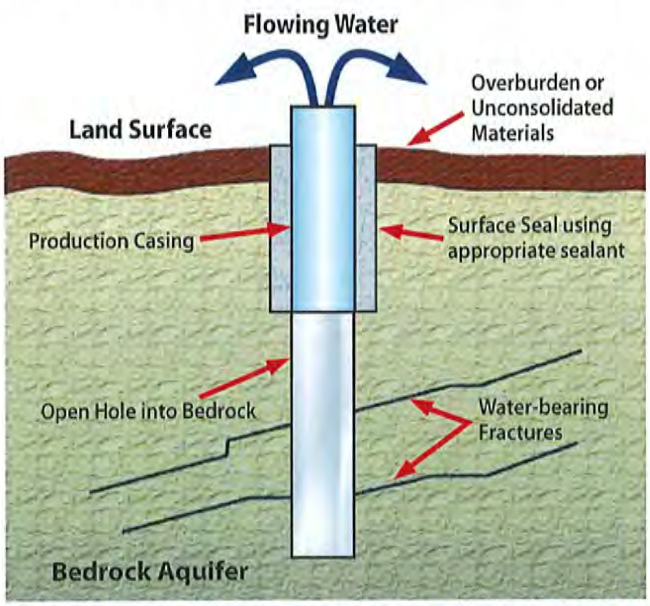

Figure 6. One possible method of completing a flowing artesian well in a bedrock aquifer.

How can flowing artesian wells be constructed in unconsolidated aquifers?

For **confined, unconsolidated aquifers** where flowing artesian conditions are likely, a cased oversized hole should be drilled into the confining layer, to allow a cement, or high solids bentonite seal to be placed between the final production casing and the outer casing (see Figure 7). This can be very complicated and expensive if the pre-drilling assessment indicates the confining layers are more than 100 ft (30 metres) deep. The size of the hole or casings and the depth of the seal must be determined on a site-by-site basis since choices are influenced by local geology and the specific artesian conditions encountered. A careful, conservative approach is recommended.

Figure 7. Bentonite cement grout seal between casings.

When constructing a well into a confined, unconsolidated flowing artesian aquifer, the appropriate sealant material between the outermost well casing and the confining layer must be of a sufficient depth and thickness to contain the flow.

Artesian conditions in **unconfined, unconsolidated aquifers** require special construction techniques such as using heavier drilling mud to counteract the pressure of the aquifer and a temporary surface casing to prevent hole collapse.

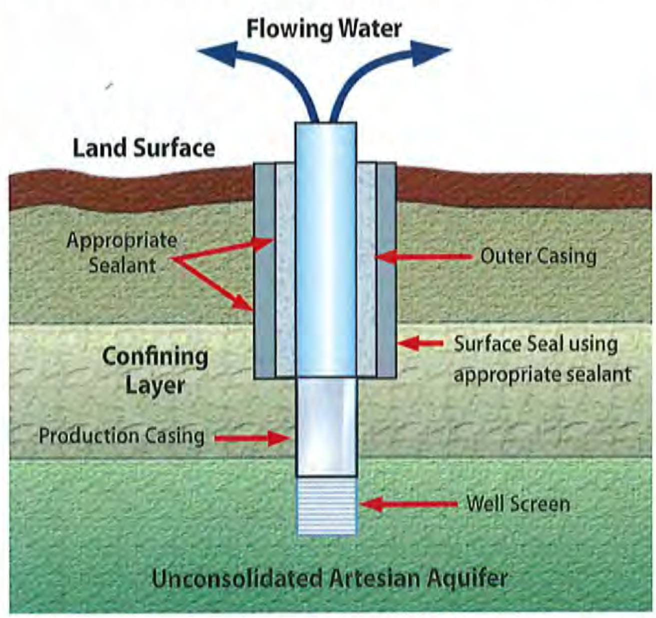

Figure 8. One possible method of completing a flowing artesian well in unconsolidated materials, e.g., sand and gravels.

What should be done if flowing artesian conditions are suddenly encountered?

When unexpected flowing artesian conditions are encountered (i.e., instant flow occurs), a qualified professional, or qualified well driller, should take control of the site and equipment should not be removed from the site until the artesian flow is under control. Contact the owner of the well and the land owner immediately to report the situation and provide plans to control the flow (see below). Steps to take include:

- control the flow,
- secure the casing or borehole, and
- protect the drill rig.

The flow may be brought under control by:

- increasing the weight of the drilling mud,
- using plugs,
- using a surge-blocking to restrict flow, or
- installing a drillable packer.

The drill pipes can be left in place in cases where the uncontrolled flow occurs in an uncased drill hole, to indicate the exact location of the hole.

If the flowing artesian well is discharging water into a wetland or surface water body, contact the local Ministry of Environment office.

It is important for the well owner (and land owner if applicable) to develop a clear understanding, potentially in the form of a contract, with the drilling contractor on how the well will be repaired and/or the flow stopped or controlled before any work on the well commences to avoid or minimize potential misunderstandings when artesian flow is encountered.

What are the key factors in completing and equipping a flowing artesian well?

Flowing artesian wells, when properly constructed, should be equipped with a device to completely stop or control the artesian flow from the well (see Figure 9). After flow is stopped, there should be no leakage up the annulus between the outermost casing and the borehole. If water does escape, the annulus should be sealed.

Figure 9. Completed high pressure flowing artesian well.

Flowing artesian wells, like all wells, need to be vented. Well caps should be equipped with a two-way vent that allows the well to inhale and exhale air as the water level changes during pumping cycles. The vent will seal the well when the pump is not in use.

Determine the shut-in pressure (see below) and record the measurement on the well construction report. The wellhead should also be designed and equipped to prevent any backflow into the well.

Where freezing conditions may occur, the wellhead of the new flowing artesian well should be covered, insulated and heated, where necessary, to prevent damage of the flow control device leading to an uncontrolled flow situation.

How is the pressure or static water level for a flowing artesian well measured?

It is important to determine and record the hydrostatic pressure of the flowing artesian well for future pre-drilling assessments. There are several ways to measure the hydrostatic pressure or static water level of a flowing artesian well:

1. Extend the well casing, or a smaller diameter pipe through a well seal on the top of the casing, high enough above the ground surface until water no longer flows out the top (without pumping). The water level in the casing extension can then be measured using a water-level sounder. The distance from the piezometric water level in the casing to the ground surface is the artesian head of the aquifer – this can be converted to pressure.

2.31 feet equals 1 psi or
0.433 psi equals 1 foot

Example

A static water level of 30 feet is converted to pressure by dividing 30 feet by 2.31 feet/psi = 13 psi.

2. A pressure gauge installed on a well seal at the top of the casing will provide the pressure reading which can be multiplied by 2.31 to find the artesian head at the gauge elevation.

How should flowing artesian wells be closed?

A qualified well driller and/or qualified professional should be hired to close a flowing artesian well and ensure that the well is closed in such a manner that there is no leakage at the surface of the ground (see Figure 10). The driller must be prepared to handle the flow from the well and the discharge of any plugging materials immediately on removal of the flow control device(s). The work site can be dangerous if the flow is not properly diverted. Closing a flowing artesian well is simplified if the flow can be overcome by extending the well casing above the artesian head. Alternatively, insert an inflatable packer or expandable rubber plug at the bottom of the casing. Physically stopping the flow may make things worse, however, which is why the rapid loading of drilling gel is often a better approach.

Another effective approach is lowering the water level by pumping from adjacent wells. A leaking annulus should be sealed (if possible) before proceeding with grouting the production casing.

Pump a high density grout such as neat cement or concrete grout with bentonite through a PVC pipe or drill rod which is lowered to the bottom of the well. The cement mixture is pumped until it reaches the land surface. Pressure grouting with a packer may be required. It may also be good to pull or perforate some of the casing to allow the grout to flow from the casing into the annulus, although this is not critical if the casing is already perforated or corroded.

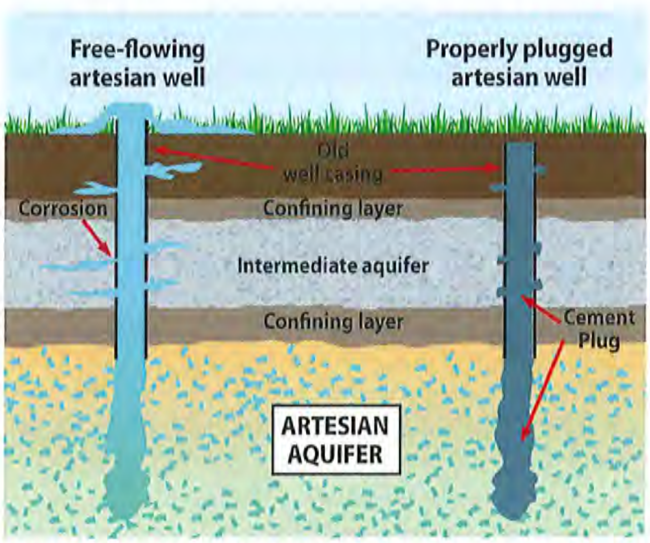

Figure 10. Example of a properly closed flowing artesian well.

How is a flowing artesian well disinfected?

Because of the protected nature of the confined artesian aquifer, flowing wells are generally less prone to bacterial contamination. Furthermore, the positive artesian pressure can minimize entry of surface contaminants into the well. Contamination introduced during the drilling process may be flushed out by the continuous discharge of water.

To disinfect a flowing well using chlorine, a temporary casing extension above the piezometric level or a tight well cap or seal can stop the flow and increase the chlorine contact time. A chlorine solution can also be pumped into the well via the secure well cap and hose connections. Once the casing extension or cap is removed, the well discharge will flush residual chlorine and inactivated bacteria from the well.

If the chlorinated water has a potential to harm the environment (e.g., fish), use an effective neutralizing agent, such as Vitamin C, to inactivate the chlorine. A solution of at least 1 per cent (by weight) of ascorbic acid is the most cost-effective form of Vitamin C. Added to the sump or a stream of chlorinated water, reaction time is nearly instantaneous.

Further Information

A registry of qualified well drillers can be found at: http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/wells/applications/well_drillers_reg.pdf.

A listing of groundwater consultants (qualified professionals) can be found at: http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/library/consultants.html.

Michigan Department of Environmental Quality, 2005. Flowing well handbook: http://www.michigan.gov/documents/deq/deq-wb-dwehs-wcu-flowwellhandbook_221323_7.pdf.

For further information on whether approvals are needed for discharging flowing artesian well water to surface water bodies, contact the local Ministry of Environment office:

Vancouver Island Region	Nanaimo	250-751-3100
Lower Mainland Region	Surrey	604-582-5200
Thompson and Cariboo Regions	Kamloops	250-371-6200
Kootenay and Okanagan Regions	Nelson	250-354-6333
	Penticton	250-490-8200
Omineca Peace and Skeena Regions	Prince George	250-565-6135

BRITISH COLUMBIA
The Best Place on Earth
Ministry of Environment

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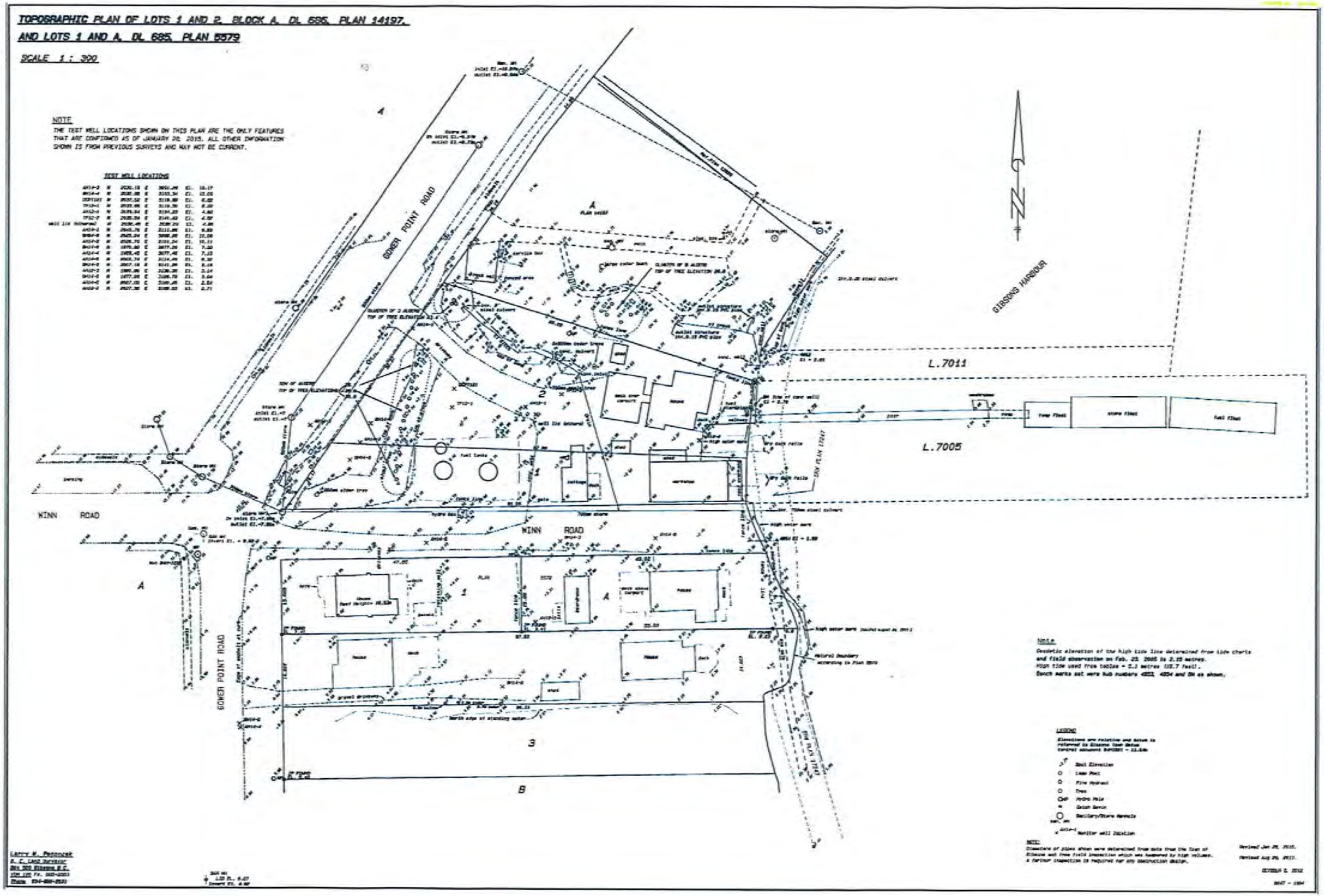
ISBN 978-0-7726-7034-2


TOPOGRAPHIC PLAN OF LOTS 1 AND 2, BLOCK A, DL 695, PLAN 14197,
AND LOTS 1 AND A, DL 685, PLAN 5579
SCALE 1 : 300
NOTE
THE TEST WELL LOCATIONS SHOWN ON THIS PLAN ARE THE ONLY FEATURES THAT ARE CONFIRMED AS OF JANUARY 20, 2015. ALL OTHER INFORMATION SHOWN IS FROM PREVIOUS SURVEYS AND MAY NOT BE CURRENT.
TEST WELL LOCATIONS
GOWER POINT ROAD
WINN ROAD
GIBSONS HARBOUR
L.7011
L.7005
A
1
2
3
B
Note
Geodetic elevation of the high tide line determined from tide charts and field observation on Feb. 25, 2005 is 2.15 metres.
High tide used from tables = 5.1 metres (16.7 feet).
Bench marks set were hub numbers 4053, 4054 and BM as shown.
LEGEND
Spot Elevation
Lamp Post
Fire Hydrant
Tree
Hydro Pole
Catch Basin
Sanitary/Storm Manhole
Monitor well location
Revised Jan 26, 2015.
Revised Aug 29, 2017.
Larry W. Penonzek
B. C. Land Surveyor

Keystone Environmental
Knowledge-Driven Results

July 7, 2016

Mr. Andre Boel, RPP
Director of Planning
Town of Gibsons
474 South Fletcher Road
PO Box 340
Gibsons, BC V0N 1V0

Dear Mr. Boel:

Re: Detailed Site Investigation
377 and 385 Gower Point Road, Gibsons, BC
Project No. P2924

We have prepared this summary of work required to complete a detailed site investigation (DSI) for 377 and 385 Gower Point Road, Gibsons, BC (the "Site"). The proposed work is to be completed under Development Permits DP-2016-04 (DPA#2 and DPA#9).

BACKGROUND

The findings of previous investigations identified the following areas of potential environmental concern (APEC) which may have impacted the Site soil and/or groundwater at levels of concern.

- **APEC 1**: A fuel storage compound was established on the southwest portion of the Site in the late 1950s to early 1960s. Up to five above ground storage tanks (ASTs) have been present within the compound and were placed on a concrete foundation covered with a bentonite seal. The condition of underlying bentonite/concrete foundation appeared to have deteriorated over time. Previous environmental investigations did not involve the collection and/or analysis of soil and groundwater samples from the area of the Site directly down-gradient to the east of the fuel storage compound.
- **APEC 2**: A pipeline runs underground between the fuel storage compound and the marina wharf located at the northeast corner of the Site. During previous environmental investigations, soil and groundwater samples were not collected and/or analyzed from the area of the Site adjacent to the pipeline.

Suite 320
4400 Dominion Street
Burnaby, British Columbia
Canada V5G 4G3

Telephone: 604 430 0671
Facsimile: 604 430 0672
info@KeystoneEnviro.com
KeystoneEnviro.com

Environmental Consulting
Engineering Solutions
Assessment & Protection

- **APEC 3:** Two gasoline underground storage tanks (USTs) were present adjacent to the north of the fuel storage compound from the late 1970s to the late 1990s. The USTs were removed in 1997. Two separate environmental investigations were conducted by others (in 1988) and by Keystone (1997). The results indicated that groundwater contamination was present in the vicinity of the original gasoline UST. However, the potential for an external source of groundwater contamination was suspected as a contributing factor in the contamination of the groundwater in the vicinity of the original UST since the contamination appeared to be related to oil and not gasoline.
- **AEC 4:** The marine repair shop (boathouse) located at the southeast corner of the Site has been historically used for repair and restoration of boats and marine equipment. The specific details regarding historic activities within the boathouse could not be established at the time of the PSI 1. Constituents of concern included engine oil, fuel, paints and solvents. Metals exceedances in shallow soils were encountered in soils east of the shed just above the high water mark.

The Stage 2 PSI included the advancement of six boreholes, four completed as groundwater monitoring wells. Concentrations of constituents of concern exceeded the Contaminated Sites Regulation (CSR) residential land use (RL) and commercial land use (CL) soil standards at the following locations:

- BH04-1 located at the former underground storage tank (UST) north central of the current aboveground storage tank (AST) farm investigated soil quality in the vicinity of the former UST. Soils exceeded the CSR RL standard for heavy extractable petroleum hydrocarbons (HEPH) but did not exceed the CSR CL standard.
- MW04-2 located at the former UST northeast of the current AST farm. This well investigated soil quality in the vicinity of the former UST and groundwater quality in the vicinity and down gradient of both former USTs. Groundwater met but did not exceed the CSR marine aquatic life (AWm) standard for pyrene.
- MW04-3 located east of the current AST farm to determine soil and groundwater quality in the assumed down gradient direction. Soils exceeded the CSR RL standards for light extractable petroleum hydrocarbons (LEPH) and HEPH but not CSR CL standards.
- MW04-4 located at the east end of the Site proximal to the fuel underground pipelines. This well investigated soil and groundwater quality along the pipeline down gradient of the AST farm. There were no soil or groundwater exceedances.
- MW04-5 located east (down gradient) of the boathouse area, investigated soil and groundwater quality down gradient of the paint stripping area. Soil exceeded the CSR CL standards for copper.
- BH04-6 located east (down gradient) of the boathouse area, investigated soil quality down gradient of the paint stripping area. Soil exceeded the CSR CL standards for chromium, copper, and zinc.

At the time of the PSI 2, soil vapour was not regulated in BC. To meet the requirements for a CofC, soil vapour at the Site will need to be investigated. Similarly, the Ministry of Environment (MOE) has now made drinking water standards applicable at all sites unless certain site specific conditions are present. Therefore, based on our knowledge of similar sites we consider it likely that CSR DW standards would apply. However, a review of the previous groundwater date against the current CSR DW standards indicated no exceedances.

Balanced Environmental collected 41 soil and/or sediment samples in the area around the boathouse and the intertidal sediments down gradient of the boathouse Analytical results indicated that an area of soil and sediment contamination for metals and some polycyclic aromatic hydrocarbons (PAH) extends from the east portion of the boathouse down to the +1.0 m chart datum (CD) mark in the intertidal area. Contamination is delineated to the west and south but only partially delineated to the east and north. Vertical delineation has not been completed. Keystone collected additional sediment samples to delineate the sediment contamination identified by Balanced, however delineation was not achieved at SED15-1.

DETAILED SITE INVESTIGATION

To meet the current requirements for obtaining a CofC from the BC Ministry of Environment (MOE), full delineation of all contaminants of concern in all media are required. Proposed investigation locations are shown on Figure 1. It is noted that soil exceedances for metals and PAH were encountered above the high water mark and in the intertidal sediments below the boathouse but has not been completely delineated horizontally or vertically in the foreshore. Therefore, sediment in the intertidal and subtidal areas of the boathouse will need to be additionally assessed. Tributyltin (TBT) analysis of the sediment is also required.

There were no soil or groundwater exceedances noted previously in the upland area, however, soil under the fuel tank farm containment area has not been investigated. Soil vapor will also need to be investigated for each of the upland APECs identified in the PSI1.

We proposed to advance two test pits in the tank farm area to 1.5–3.0 m after it has been decommissioned to assess for contamination under the facility. A third test pit will be advanced north of Balanced Environmental's sample #15 location to delineate the metals contamination previously encountered. The DSI test pitting will be coordinated with the geotechnical test pit investigation where possible to reduce the number of test pits required.

Four shallow test pits will also be advanced in the intertidal area to depth of 1–1.5 m and sediment samples collected in the contaminated intertidal zone to vertically delineate the sediment contamination previously identified. Three surficial ponar grab samples will also be collected to complete lateral delineation of sediment contamination north, east and west of SED15-1. An additional four surface sediment samples (ponar or surface grab at low tide) will be collected, at locations to be determined, for TBT analysis.

Three monitoring wells will be advanced in the boathouse area, one within the foot print of the boathouse, one to the north and one to the west to confirm metals and PAH concentrations in the shallow aquifer. Keystone Environmental will not be drilling into the deeper Gibsons Aquifer at the Site. One monitoring well will be advanced in the tank farm area to confirm groundwater quality under the tank farm. Groundwater monitoring wells will be drilled to an estimated 3–4 mbgs to intercept the shallow groundwater table.

Soil samples will be analysed for concentrations of benzene, toluene, ethylbenzene and xylenes (BTEX), volatile petroleum hydrocarbons (VPH), LEPH and HEPH and metals. Sediment samples will be analyzed for concentrations of PAHs, metals and TBT. Groundwater will be analyzed for concentrations of BTEX, VPH, LEPH, HEPH, PAHs and metals in the tank farm area and PAHs and metals in the boathouse area.

Soil vapour probes will be installed in each of the four monitoring wells and additional shallow drive point soil vapour probes will be installed near MW04-3 and MW04-2.

Upon receipt of the analytical results from the lab, the results will be compared to the CSR CL standards for soil, the CSR sediment quality criteria for typical sites ($SEDQC_{TS}$), the PSDDA criteria for TBT, the CSR CL vapour standards for soil vapour and the CSR drinking water (DW) and marine aquatic life (AW_m) standards for groundwater.

ENVIRONMENTAL MITIGATION MEASURES

As discussed previously, our proposed sampling activities in the foreshore habitat will include three ponar grab samples collected from a boat and four other surface sediment samples collected by Ponar or by a shovel (if above the tide line). Ponar samples are low impact surface grab samples that collect approximately 0.15 m of sediment. In addition, four test pits will be excavated in the foreshore sediments to 1–1.5 m to vertically delineate the sediment contamination in accordance with the requirements of the Contaminated Sites Regulation. The sediment test pits are considered to be shallow enough to not impact the Gibsons Aquifer.

The test pits will be excavated using a tracked excavator at low tide. The excavator will access the test pit locations via the concrete pads of the former boat launch where practical. Prior to entering the foreshore, the excavator will be inspected for leaks and cleaned of excess grease or oil. A Keystone Environmental staff member will be on-site as an environmental monitor (EM) to observe the work and will have the authority to stop work in the event of a release or observed potential for release. The sediments in the area to be sampled are sands and gravels with cobbles and, therefore, generation of significant turbidity is not anticipated. The EM will conduct turbidly monitoring as required to document induced turbidity relative to provincial water quality guidelines. In the event that significant turbidity, exceeding the guidelines, is observed, the EM will have the authority to stop work and require that silt fences/silt curtains or other suitable turbidity control measure(s) be implemented.

Sediments excavated during the text pitting will be placed on plywood sheets above the tideline for sampling and then returned to the source test pit once the samples have been collected.

Also, Keystone Environmental will observe the geotechnical test pits excavated by Horizon Engineering Inc. (Horizon) to appropriately address potentially contaminated soils that may be encountered. It is our understanding that Horizon will also attend Keystone's DSI sampling program to monitor that the drilling and test pit excavation does not penetrate the underlying Gibsons Aquifer.

For the drilling of the monitoring wells, Keystone Environmental will use a Sonic Drill rig to advance the boreholes. Keystone will advance the boreholes in maximum 1.5 m flytes to mitigate against inadvertently penetrating the Gibsons Aquifer. The sonic rig uses a steel casing that will provides a seal to the hole in the event that the Gibsons Aquifer is breached and permits the hole to be grouted and sealed. A detailed procedure for the proposed drilling program, including measures to address the potential for an accidental aquifer breach, is attached.

We judge that if the proposed subsurface investigation is carried out in accordance with the methods described in the attached proposed drilling program, there should be no impact to the Gibsons Aquifer.

We trust this provides the information you currently require, please contact this office at your earliest convenience if you have any questions.

Yours truly,

Keystone Environmental Ltd.

Michael Geraghty, M.Sc., P.Geo.
Senior Technical Manager

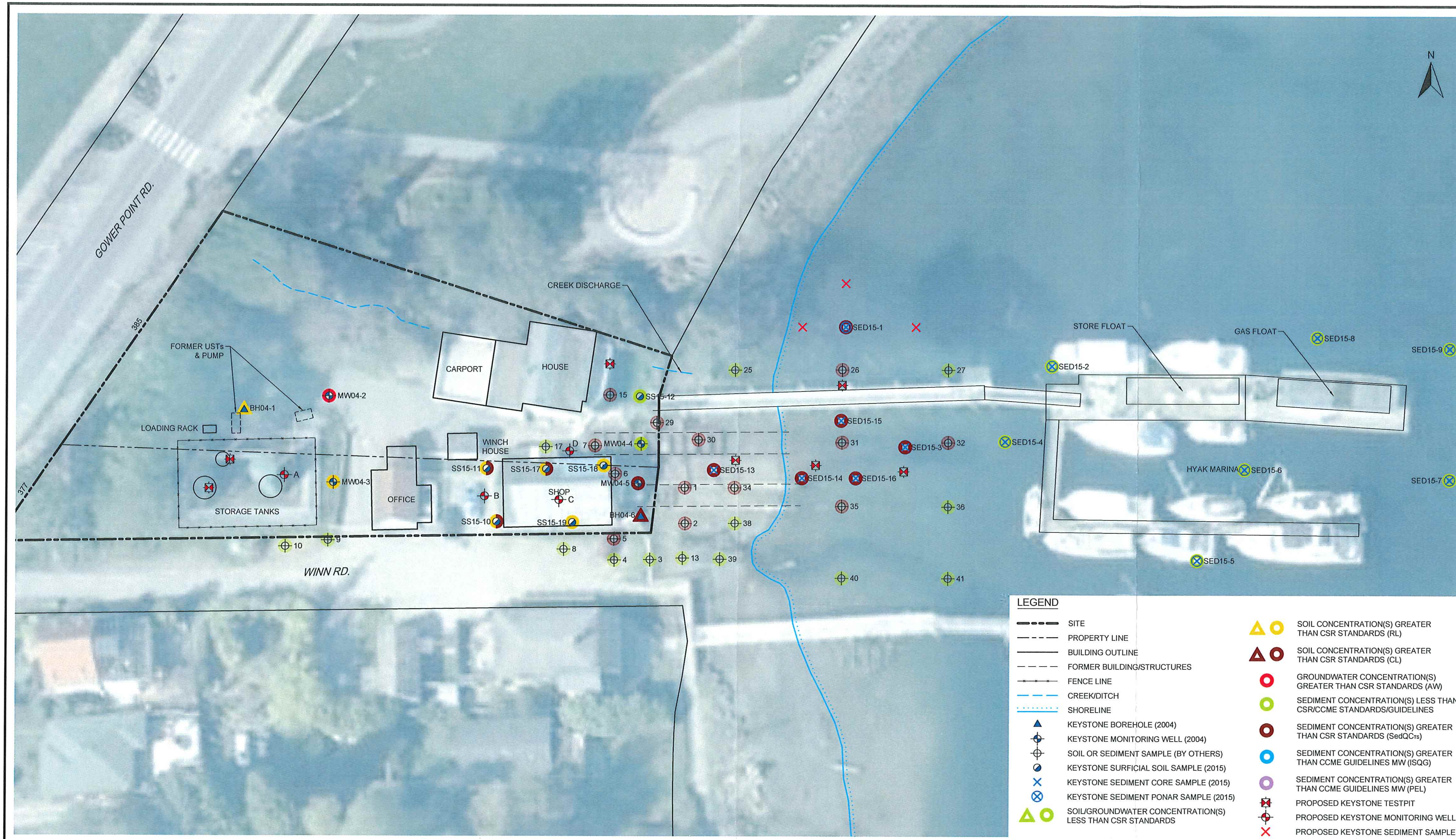
I:\12800-12899\12845\Correspondence\12845 160707 Gibsons DSI Letter.docx

ATTACHMENTS:

- Figure 1
- Drilling Program

cc: Susan Hildebrand, Klaus Fuerniss Enterprises Inc.

FIGURE



Keystone Environmental

NOTES:
1. THIS DRAWING IS FOR GENERAL INFORMATION ONLY. LOT BOUNDARIES AND FEATURES ARE APPROXIMATE.
2. DATE OF AERIAL PHOTO IS 2014.

5m 0 25m

SCALE: 1:500(approx.)

377 & 385 Gower Point Road
Gibsons, B C
Klaus Fuerniss Enterprises Inc.

REVISION No.	DATE	PROJECT No.
01	July 2016	12845-04

Figure 1
Proposed Sample Location Plan

PLOT SCALE: 1:1 DRAWN BY: DK CADD FILE No. 12845\Figs\Proposal\Fig1-Proposal-R1.dwg

DRILLING PROGRAM

Keystone Environmental
Knowledge-Driven Results

Proposed Drilling Program for "The George" Project

<u>Submitted to</u>: The Town of Gibsons

<u>Date Issued</u>: July 7, 2016

<u>Prepared by</u>: Keystone Environmental Ltd.

<u>cc</u>:	Town of Gibsons Representative:	Dave Newman – Director of Engineering
	Town's representative:	TBD
	Barge Operator:	N/A
	Drilling Contractor:	Mud Bay Drilling Co. Ltd.
	Vacuum Truck Contractor:	Bonniebrook Industries

<u>Contact List</u>:

EMERGENCY NUMBERS	
Town of Gibsons Representative:	Dave Newman (work 604-886-2274 ext 212, cell 604-741-8370)
Mud Bay Drilling Representative:	Mike Parkinson (work 604-888-2206, cell 604-788-5528)
Keystone Environmental	Michael Geraghty (604-970-9421)
Ambulance/Hospital:	911

PRIME CONSULTANT IN CHARGE (KEYSTONE ENVIRONMENTAL)	
Project Manager:	Michael Geraghty (work 604-430-0671, cell 604-970-9421)
Field Supervisor:	Christopher Homes (work 604-430-0671, cell 778-233-0655)

TOWN REPRESENTATIVE (TBD)	
Town Representative:	

SERVICE COMPANIES	
Drilling Contractor:	Driller: Ian Taylor (work 604-888-2206, cell 604-880-5181)
Grouting/cement contractor:	Mud Bay Drilling
Vacuum Truck:	Bonniebrook Industries (work 604-886-7064)
Waste Removal Contractor:	N/A
Barge Operator:	N/A

1. OVERVIEW

1.1 Purpose

The purpose of the subject drilling program is to determine is soil contamination at the Site has impacted the shallow groundwater aquifer. The objective is to install four (4) groundwater wells in such a manner as to **not** penetrate the underlying Gibsons Aquifer at the site.

1.2 Aquifer

The proposed drilling area is underlain by a known artesian aquifer (the Gibsons Aquifer, BC Aquifer # 560) and therefore, an increased standard of care is needed to protect the aquifer during investigative work.

Based on the Town of Gibsons Aquifer Mapping study (2013) prepared by Waterline Resources Inc., piezometric heads of over 15 m (50 ft) above sea level are understood to be possible if the aquifer is penetrated. In addition, at Town Well 1, artesian flow in excess of 7.6 L/s (100 Igpm) was noted at the time of drilling.

1.3 Risks

We envisage that the following risks would be involved in the proposed drilling program:

1. Uncontrolled artesian flow if the aquitard is breached and control of the well is lost.
2. Development of a sinkhole if artesian flow is left unattended or site personnel are unprepared to mitigate the flow.
3. Impact on the Town of Gibsons' water wells if the aquifer is breached and left unsealed.
4. Potential loss of aquifer pressure if the aquifer is breached and not sealed properly.

1.4 Proposed Drilling Program

Table 1 summarizes the proposed drilling program with anticipated depth, location, and installation plan for each hole. The proposed borehole locations are shown on Figure 1.

Table 1: Proposed Boreholes

Temporary ID	Proposed Location	Expected Depth	Installation Plan
BH16-A	North of Winn Rd., in the former Storage Tank Area, west of MW04-3 and south of BH04-1. Precise location to be determined on site.	Approximately 4.5 to 6 metres (15 to 20 feet). Hole will be terminated as soon as till-like materials or artesian pressures are encountered.	Install one monitoring well in the upper unconfined aquifer, to the confirmed depth to the top of the confining layer (if present at this location)
BH16-B	North of Winn Rd., between the former office and shop buildings, south of the Winch house. In between SS15-11 and SS15-10. Precise location to be determined on site.	Approximately 4.5 to 6 metres (15 to 20 feet). Hole will be terminated as soon as till-like materials or artesian pressures are encountered.	Install one monitoring well in the upper unconfined aquifer, to the confirmed depth to the top of the confining layer (if present at this location)
BH16-C	North of Winn Rd., in the former Shop Area, in between SS15-19 and SS15-17. Precise location to be determined on site.	Approximately 4.5 to 6 metres (15 to 20 feet). Hole will be terminated as soon as till-like materials or artesian pressures are encountered.	Install one monitoring well in the upper unconfined aquifer, to the confirmed depth to the top of the confining layer (if present at this location)
BH16-D	North of Winn Rd., and north of the former Shop Area, west of MW04-04, in between sample 7 and 17 (by others). Precise location to be determined on site.	Approximately 4.5 to 6 metres (15 to 20 feet). Hole will be terminated as soon as till-like materials or artesian pressures are encountered.	Install one monitoring well in the upper unconfined aquifer, to the confirmed depth to the top of the confining layer (if present at this location)

2. PRE- DRILLING REQUIREMENTS

The following have been established:

1. Knowledge and understanding of BC's Groundwater Protection Regulations.
2. WorkSafe BC program (site specific H&S requirements including traffic control, special considerations).
3. Permit Requirements: We understand that the only permit requirements are from the Town of Gibsons.
4. Driller certification: Training certification documents for the driller that will be conducting the subject drilling program (Ian Taylor) is attached. Certifications for the drillers helpers (Ryan Berg and Brad Mackenzie) are attached.
5. All rig lifting equipment, and overhead equipment will be certified to the Original Equipment Manufacturers Specifications (OEM).
6. Casing running procedures: 4" Core Barrel, drill rods, and 6", 7", and 8" casing to be presented to the drill head by way of "rod/casing handler". This mechanical device allows for the safe connection of the drill string without the added risk of crew members physically holding rods or casing while they turn into the drill head.
7. Certificate of Insurance and WorkSafeBC letters are attached.

8. Drill rig specifications (Sonic DB320) are attached.

3. RIG MOVE, RIG UP, AND SITE SAFETY

The following procedures and site safety provisions will be followed during mobilizing, set up, and operation of the drill rig:

1. Mud Bay to contact Keystone Environmental the day before drilling to confirm that the site and drill are ready.

2. Move in and rig up drilling rig and auxiliary equipment on site. Prior to initiating drilling, carry out detailed rig inspection and report any unsafe conditions to Keystone Environmental.

3. Hold a pre-drilling safety meeting with the rig crew and site personnel and discuss the Hazardous Operations and drilling program.

4. Certified driller from Mud Bay to be on site at all times during drilling.

4. GENERAL SONIC DRILLING PROCEDURES

4.1 Roles and Responsibilities.

1. Mud Bay will operate all drilling and auxiliary equipment, retrieve soil samples, install standpipes, and seal boreholes.

2. Keystone Environmental will carry out utility locate search, indicate possible drilling locations, log stratigraphy, collect representative soil samples and direct monitoring well installation.

3. Keystone Environmental's field hydrogeologist will be on site to supervise monitoring well installation and sealing of test holes, as required, to ensure that there is no adverse impact on the aquifer.

3. Waterline (as the Town's representative) will review drilling operations, electrical conductivity data, standpipe installation and hole sealing procedures to ensure that the integrity of the aquifer is maintained. Waterline will report directly to the Town of Gibsons' Director of Engineering.

4.2 Methodology of Data and Sample Collection

1. A field supervisor from Keystone Environmental will be on site to collect select soil samples at regular intervals and at changes of soil condition, or at particular zones of interest. Keystone's field hydrogeologist will be on site to supervise monitoring well installation and sealing of test holes, as required, and to verify that all measures are taken to maintain the integrity of the aquifer.

2. Soil samples will be transported to the analytical laboratory (Maxxam Analytics) for soil analysis.

6. Static head elevations will be estimated if shallow groundwater is encountered.

4.3 Drilling Details

4.3.1 Borehole BH16-A

This proposed borehole will be drilled vertically at the location and to the depth noted in Table 1, which assumes that the top of the aquitard (confining layer, if present) will be encountered between 2.4 and 5.2 metres depth (8 to 17 feet). The actual termination depth of this borehole will be finalized in the field based on observations of cutting samples, borehole advancement rates, EC data, and the presence of confining materials (if present). We plan to terminate the hole as soon as the confining layer or artesian groundwater is observed. The borehole will generally be advanced as follows, as illustrated in the attached "Sonic Drilling System" brochure:

1. Sonically advance core barrel into the undisturbed soil, typically 3.0 metres per run (i.e., before retrieving the soil sample), targeting the unconsolidated soils above the confining layer (i.e. the underlying glacial till, where present). Vibration and rotation only will be used to advance the core barrel. The confining layer (glacial till) is expected to be encountered at 4.0 metres (13 feet) depth based on the closest borehole logs.

2. Sonically override a larger diameter casing over the core barrel using water to clear the annulus.

3. Return the core barrel to the surface for sample extraction and logging by Keystone.

4. Complete coring and overriding casing advancement to desired depth.

5. Field Environmental Scientist to complete soil description, logging and collect representative samples and EC data as previously described.

6. Keystone field Hydrogeologist to observe the process and assist wherever possible, as previously described.

7. Between runs, measure water level and collect salinity reading to confirm seawater or fresh water inside casing.

8. If the aquitard soil (understood to be comprised of glacial till), aquifer materials (understood to be comprised of coarse grained sand and/or gravel) and/or artesian pressures are encountered, the hole would be terminated immediately and completed / sealed as described in sections 4.3.5 through 4.3.7 below.

4.3.2 Borehole BH16-B

This proposed borehole will be drilled vertically at the location and to the depth noted in Table 1, which assumes that the top of the aquitard (confining layer, if present) will be encountered between 2.4 and 5.2 metres depth (8 to 17 feet). The actual termination depth of this borehole will be finalized in the field based on observations of cutting samples, borehole advancement rates, EC data, and the presence of confining materials (if present). We plan to terminate the hole as soon as the confining layer or artesian groundwater is observed.

4.3.3 Borehole BH16-C

This proposed borehole will be drilled vertically at the location and to the depth noted in Table 1, which assumes that the top of the aquitard (confining layer, if present) will be encountered between 2.4 and 5.2 metres depth (8 to 17 feet). The actual termination depth of this borehole will be finalized in the field based on observations of cutting samples, borehole advancement rates, EC data, and the presence of confining materials (if present). We plan to terminate the hole as soon as the confining layer or artesian groundwater is observed.

4.3.4 Borehole BH16-D

This proposed borehole will be drilled vertically at the location and to the depth noted in Table 1, which assumes that the top of the aquitard (confining layer, if present) will be encountered between 2.4 and 5.2 metres depth (8 to 17 feet). The actual termination depth of this borehole will be finalized in the field based on observations of cutting samples, borehole advancement rates, EC data, and the presence of confining materials (if present). We plan to terminate the hole as soon as the confining layer or artesian groundwater is observed.

4.3.5 Monitoring Well Installation Details

Monitoring wells are planned to be installed in all four boreholes as follows:

1. Check the observed shallow groundwater level at the completion of the borehole drilling, to ensure an artesian condition is not present (if present see Section 4.3.6).

2. Lower the nominally 50mm diameter PVC screen and riser pipe (PVC slotted screen in lower portion, PVC solid in upper portion) to the bottom of the borehole.

3. With the use of a tremie line, place silica filter sand adjacent to the screened section of the piezometer.

4. Design piezometer installation materials to correlate with the removal of the drill casings (i.e. Install 1.5 m of piezometer material, and then remove 1.5 m of casing).

5. Place a nominally 0.6 m thick bentonite seal above silica sand filter pack using tremie line in same manner as installation of silica sand. Use bentonite coated pellets in the place of chips if necessary.

6. Above the bentonite seal, grout the remaining annular space with a weighted cement grout mix to ensure that the grout seals against the borehole walls.

7. When placing grout (Cement / bentonite mixture) in the annular space, the weight and volume of grout should be calculated to balance any surficial formation water pressure at a depth below the bottom of the steel drill casing, so that the casing can subsequently be removed.

8. The grout (calculated weight and volume) is placed by tremie into the annular space above the bentonite seal to a depth estimated to be below the bottom of the steel drill casing. This drill casing is then retracted to a depth estimated to be above the level of the grout column. Pressure grouting may be required if the above is found to be inadequate.

9. The grout should be brought to a level within 0.3m from surface. The depth to grout shall be measured and monitored to determine if the seals heave during grout set. Allow the grout to set.

10. Upon completion, groundwater should be present in the piezometer, but the well should NOT be artesian, and NO flow should be present in the annular space at the ground surface.
11. The remaining 0.3 m will be used to install a flush-mount wellhead protector, and concrete surface plug.
12. The completed monitoring well will be visually monitored by site personnel (Keystone or the owner's representative) throughout the rest of the day and for subsequent days. Any sign of flow from the borehole would be reported to Keystone immediately, and remedial action would be taken as soon as possible (which may require re-mobilization of drilling equipment to the site).

4.3.6 Borehole Abandonment Program (Flowing Artesian Hole, if Piezometer Not Installed)

If flow artesian conditions are encountered (penetration of the confined aquifer);

1. If artesian conditions are encountered and water is flowing out the top of the casing, short pieces of casing could be added until the water stops flowing or is reduced to a small flow that will allow the placement of bentonite chips and pellets by gravity. A cap would be placed with a pressure gauge onto the top of the casing to determine the artesian pressure before adding supplementary casing lengths. The location of each borehole will be surveyed based on a common datum.
2. Backfill with bentonite chips from the bottom of the borehole to the top of the confining layer (if present). Confirm that artesian flow has stopped prior to proceeding prior to completely pulling the casing.
3. Once artesian flow has stopped, backfill on top of the bentonite chips with a layer of coated bentonite pellets.
4. Mix a recipe of Portland cement and barite as heavy as possible and still be able to pump into the casing from the top of the bentonite pellets to the surface. Take the 'Mud Balance' to measure the weight of the 'heavy cementatious grout' so that we know the pressure of the grout column that is placed to balance any artesian water pressure that may be encountered. We want to place the bentonite to act as a 'plug' into the aquifer. If we did not place this bentonite plug, the cementatious grout may 'disappear' into the aquifer.
5. No casing would be removed prior to confirming control of any artesian flow.
6. Allow cement/bentonite to set and confirm seal before moving off the location.
7. Sufficient volume of fresh water would be on site for the mixing of the cementatious grout.
8. Larger diameter casing will be available to override the 6" casing should the artesian flow through an annular space between the 6" casing and borehole wall.
9. Storage capacity would be available on site for the collection of any drill fluid returned to the surface.
10. The completed hole will be visually monitored by site personnel (Keystone or the owner's representative) throughout the rest of the day and for subsequent days. Any sign of flow from the hole would be reported to Keystone immediately, and remedial action would be

taken as soon as possible (which may require re-mobilization of drilling equipment to the site).

4.3.7 Borehole Abandonment Program (Non-Flowing / Non-Artesian Hole, if Piezometer Not Installed)

If the drilled boreholes are to be abandoned without installing a well tube;

1. Backfill with bentonite chips from the bottom of the borehole to form a base plug.
2. Grout the borehole to within 0.3 m (1 ft) of surface.
3. The completed hole will be visually monitored by site personnel (Keystone or the owner's representative) throughout the rest of the day and for subsequent days. Any sign of flow from the hole or heave in the grout seal would be reported to Keystone immediately, and remedial action would be taken as soon as possible (which may require re-mobilization of drilling equipment to the site).
4. Once the well plug is determined to be holding, install a cement plug at surface.

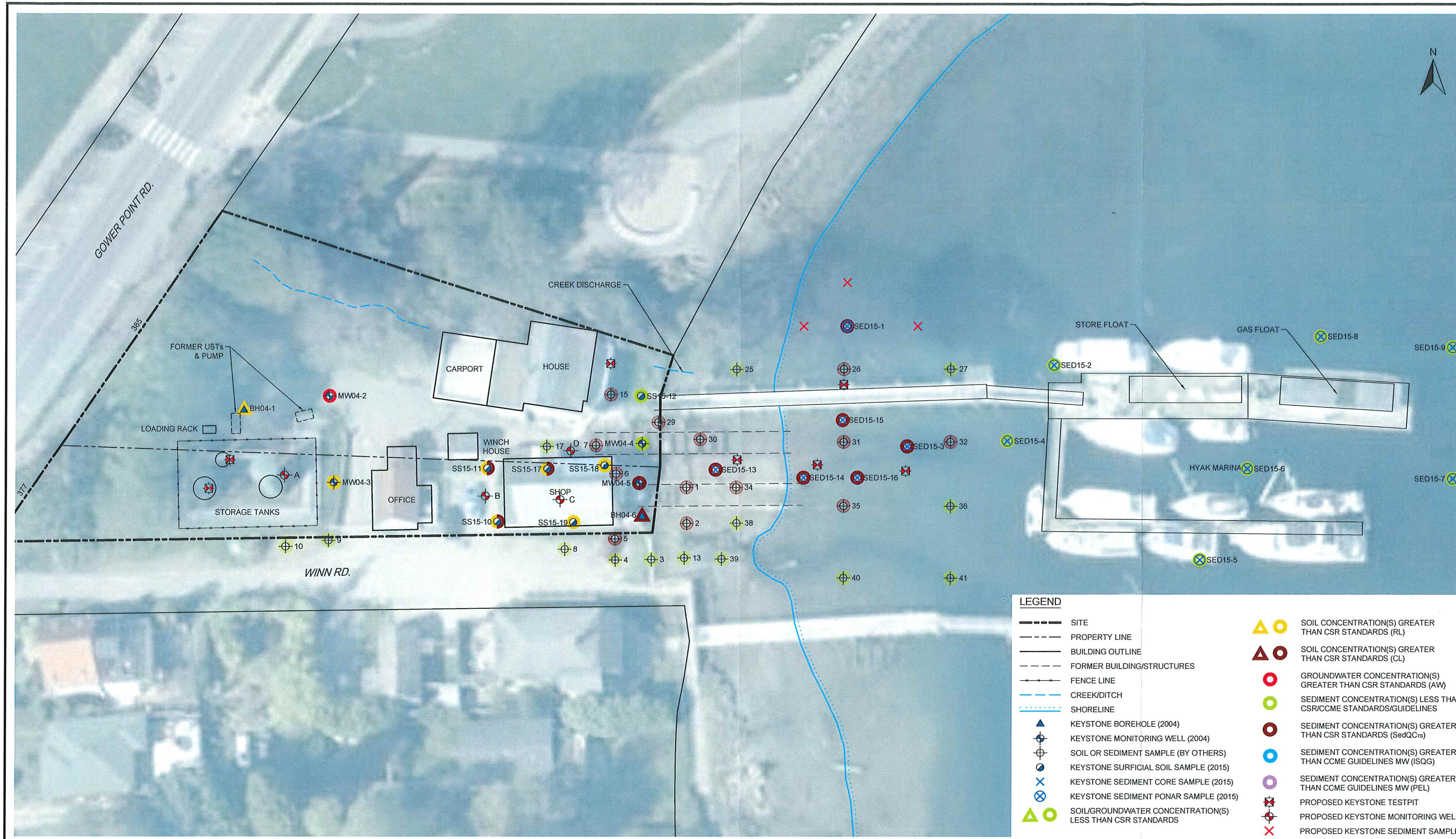
5. FIELD PACKAGE

The following documents are attached:

1. Figure 1: Proposed test hole location plan
2. Sonic Drilling System brochure
3. Mud Bay's Sonic DB320 drill rig specifications sheet
4. Mud Bay drillers' safety training records
5. Mud Bay Drilling's WorkSafe BC letter
6. Mud Bay Drilling's Certificate of Insurance
7. BC Ministry of Environment "Flowing Artesian Well" document
8. Site Plan

The following signees read this document and understand their responsibilities and agree to implement the requirements of this document.

Name	Company	Position	Signature



Keystone Environmental

NOTES:
1. THIS DRAWING IS FOR GENERAL INFORMATION ONLY. LOT BOUNDARIES AND FEATURES ARE APPROXIMATE.
2. DATE OF AERIAL PHOTO IS 2014.

5m 0 25m

SCALE: 1:500(approx.)

377 & 385 Gower Point Road
Gibsons, B C
Klaus Fuerniss Enterprises Inc.

REVISION No.	DATE	PROJECT No.
01	July 2016	12845-04

Figure 1
Proposed Sample Location Plan

PLOT SCALE: 1:1 DRAWN BY: DK CADD FILE No. 12845\Figs\Proposal\Fig1-Proposal-R1.dwg

SONIC DRILLING SYSTEM

BOART LONGYEAR™

THE LEADER IN SONIC DRILLING TECHNOLOGY

Whether your drilling needs are for environmental water supply development, geoconstruction, geotechnical or mineral exploration, Sonic drilling technology offers **several distinct advantages** over conventional drilling:

BENEFITS OF SONIC

SUPERIOR INFORMATION

Sonic drilling provides a continuous, relatively undisturbed core sample of unparalleled quality and accuracy through any type of formation. When using the iso-flow groundwater profiling system, hydrogeological and
geochemical data can be easily obtained.

WASTE REDUCTION

Sonic drilling reduces waste by up to 80% relative to conventional methods.

Boart Longyear
Competitor

(Amount of waste typical for a 100' installation of a 2" monitoring well.)

SUPERIOR WELL CONSTRUCTION

Sonic drilling causes minimal disturbance to the surrounding borehole wall, resulting in more efficient well development and performance.

SPEED

Sonic drilling is two to three times faster than conventional overburden drilling methods.

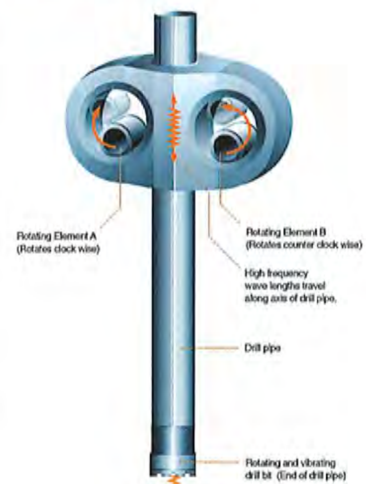
RISK MINIMIZATION

Sonic drilling greatly reduces the risk of project failure due to unknown or difficult subsurface conditions. Projects finish on time and on budget. Sonic drilling obtains the lowest total project cost possible.

FLEXIBILITY

Sonic drilling advances a temporary outer casing as the borehole is drilled, allowing you to do more within a single borehole.

OSCILLATOR DIAGRAM



Oscillator Detail

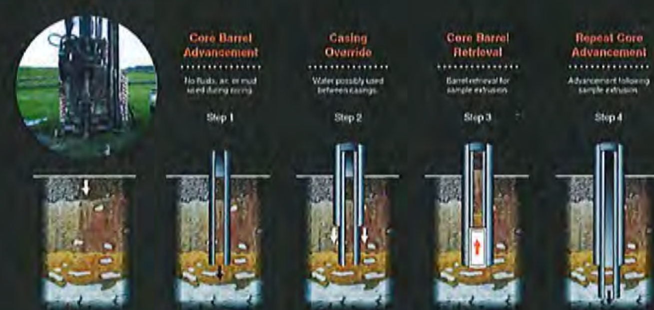
HOW SONIC DRILLING WORKS

Sonic drilling employs the use of high-frequency, resonate energy to advance a core barrel or casing into subsurface formations. During drilling, the resonant energy is transferred down the drill string to the bit face at various Sonic frequencies. Simultaneously rotating the drill string evenly distributes the energy and impact at the bit face.

The resonant energy is generated inside the Sonic head by two counter-rotating weights. A pneumatic isolation system inside the head prevents the resonate energy from transmitting to the drill rig and preferentially directs the energy down the drill string.

The Sonic driller controls the resonant energy generated by the Sonic oscillator to match the formation being encountered to achieve maximum drilling productivity. When the resonant Sonic energy coincides with the natural frequency of the drill string, resonance occurs. This results in the maximum amount of energy being delivered to the face. At the same time, friction of the soil immediately adjacent to the entire drill string is substantially minimized, resulting in very fast penetration rates.

SONIC DRILLING PROCEDURE



SONIC BOREHOLE ADVANCEMENT

The Sonic drilling method advances a casing as the borehole is drilled. While there are several ways to drill a bore hole with the Sonic drilling method (depending upon site-specific conditions and project objectives), the most common means involves advancing a core barrel, which is overridden by a larger diameter drill string that cases the open borehole and prevents collapse.

Typical Sonic drilling procedure:
1. Sonically advance core barrel into the undisturbed formation. No air, mud or water is used in the coring process.
2. Sonically override a larger diameter casing over the core barrel.
3. Return the core barrel to the surface for sample extraction.
4. Complete coring and overriding casing to desired depth.

- Core sizes of 3" through 8" are available.
- Standard borehole sizes of 3" through 12" can be drilled.
- Depths in excess of 600' in a variety of formations and conditions.

WORLDWIDE DRILLING SERVICES

Offices Worldwide:

GLOBAL HEADQUARTERS
UNITED STATES
Tel: +1 (800) 461-7333

CANADA
Tel: +1 (705) 474-2800

EUROPE
Tel: +44 (0) 1259 727780

AFRICA
Tel: +27 83 300 1593

AUSTRALIA
Tel: +61 8 9352 9600

LATIN AMERICA
Tel: +56 2 361 6361

We invite you to contact Boart Longyear and learn more about Sonic drilling and how it can assist you in meeting your drilling needs.

www.boartlongyear.com

BOART LONGYEAR™

› Sonic DB320

Sonic DB320

Our DB320 is a compact, lightweight drill rig especially designed for sonic drilling through unconsolidated material. It has been optimised to extract more comprehensive core samples in sand, clay or gravel than is usually possible with traditional soil sampling techniques.

Height:	Mast up	26' (7.92m)
	Mast down	9' 5" (2.86m)
Length:	With Mast	24' (7.32m)
Width:	6' 8" (2.07m) deck width	
Weight:	12,050 kg (26,566 lbs)	
Torque:	240 da N.M.	
Grnd Pressure:	.037 Mpa (5.4 psi)	
Climbing:	60% (30°)	
Sound Level:	<76 dbA @ 10m	
Equipped:	Skid Steer (Bobcat) for support	
	Rotary Safety Guards	
	Rod / Casing Handler	
	SPT Auto-Hammer	

Capable Of:

- Continuous 4" x 6" Sonic Soil Sampling to 50m (164 ft)
- 7" and 8" Core Barrels Available
- Angle Drilling
- Iso-Flow Sampling
- All Geotechnical Testing
  - SPT, Shelby, Vane Testing
  - Deploying CPT

40+ YEARS OF EXPERTISE SINCE 1972

MUD BAY DRILLING CO. LTD.

a sonic drilling partnership with BOART LONGYEAR

www.mudbaydrilling.com

Surrey: 19545 Telegraph Trail / Surrey BC, Canada V4N 4G9 / p. (604) 888.2206 / f. (604) 888.4206
Kelowna: 3334 Sexsmith Road / Kelowna BC, Canada V1X 7S5 / p. (250) 765.2210 / f. (250) 769.4206

Employee Certificate List
Ian Taylor

Certificate	Compliance	Certificate #	Issue Date	Expiry Date
CN - CP E Rail Safe	**Required**	**59405**	**20-Feb-2014**	**20-Feb-2017**
Commercial Vehicles	Optional		22-Jan-2016	22-Jan-2019
CSTS	**Required**		**27-Nov-2012**	
Directing Vehicles	**Required**		**22-Feb-2016**	**22-Feb-2019**
Driver Improvement / Defensive Driving	Optional		05-Jan-2015	
Driver's License	**Required**		**07-May-2013**	**22-May-2018**
Fire Safety	**Required**		**12-Jan-2015**	**12-Jan-2018**
First Aid / CPR	**Required**		**07-Jan-2016**	**07-Jan-2019**
Forklift Operator	**Required**		**04-Jan-2016**	**04-Jan-2019**
Ground Disturbance	**Required**		**06-Jan-2016**	**06-Jan-2019**
Hazard Identification and Risk Assesment	Optional		05-Jan-2015	
Hearing Test	**Required**		**06-Jan-2016**	**06-Jan-2017**
Hours of Service	**Required**		**22-Jan-2016**	**22-Jan-2019**
Imperial Oil RRS	**Required**		**04-Jan-2016**	**04-Jan-2017**
LPS AECOM	Optional		11-Mar-2016	11-Mar-2018
LPS Interim	**Required**		**22-Jan-2016**	**22-Jan-2017**
Port Pass	**Required**		**30-Nov-2012**	**30-Nov-2017**
POST	**Required**		**01-Jan-2016**	**01-Jan-2017**
Respirator Fit Testing	**Required**		**06-Jan-2016**	**06-Jan-2017**
Shell Life Saving Rules	**Required**		**04-Jan-2016**	**04-Jan-2017**
Skid Steer Certification	**Required**		**04-Jan-2016**	**04-Jan-2019**
Suncor - Journey to Zero	**Required**		**04-Jan-2016**	**04-Jan-2017**
Transportation Endoresment	**Required**		**08-Jan-2016**	**08-Jan-2019**
Transportation of Dangerous Goods (TDG)	**Required**		**07-Aug-2014**	**07-Aug-2017**
WHMIS	**Required**		**22-Jan-2016**	**22-Jan-2019**
Wildlife Awareness	Optional		25-Jul-2013	25-Jul-2016

Note: This report does NOT include optional certificates that are missing or expired.

Employee Certificate List
Kensil (Ryan) Berg

Certificate	Compliance	Certificate #	Issue Date	Expiry Date
CN - CP E Rail Safe	**Required**		**30-Jul-2013**	**30-Jul-2016**
Commercial Vehicles	Optional		04-Jan-2016	04-Jan-2019
CSTS	**Required**		**03-May-2012**	
Directing Vehicles	**Required**		**Missing**	
Driver Improvement / Defensive Driving	**Required**		**06-Jan-2016**	**06-Jan-2021**
Driver's License	**Required**		**03-Jan-2014**	**16-Nov-2018**
Fire Safety	**Required**		**04-Jan-2016**	**04-Jan-2019**
First Aid / CPR	**Required**		**07-Jan-2016**	**07-Jan-2019**
Forklift Operator	**Required**		**04-Jan-2016**	**04-Jan-2019**
Ground Disturbance	**Required**		**22-Jan-2016**	**22-Jan-2019**
Hazard Identification and Risk Assesment	Optional		05-Jan-2015	
Hearing Test	**Required**		**06-Jan-2016**	**06-Jan-2017**
Hours of Service	**Required**		**04-Jan-2016**	**04-Jan-2019**
Imperial Oil RRS	**Required**		**04-Jan-2016**	**04-Jan-2017**
LPS AECOM	Optional		11-Mar-2016	11-Mar-2018
LPS Interim	**Required**		**21-Jan-2016**	**21-Jan-2017**
Port Pass	**Required**		**08-Nov-2014**	**08-Nov-2018**
POST	**Required**		**01-Jan-2016**	**01-Jan-2017**
Respirator Fit Testing	**Required**		**06-Jan-2016**	**06-Jan-2017**
Shell Life Saving Rules	**Required**		**04-Jan-2016**	**04-Jan-2017**
Skid Steer Certification	**Required**		**28-May-2014**	**28-May-2017**
Suncor - Journey to Zero	**Required**		**04-Jan-2016**	**04-Jan-2017**
Transportation Endoresment	**Required**		**08-Jan-2016**	**08-Jan-2019**
Transportation of Dangerous Goods (TDG)	**Required**		**22-Aug-2014**	**22-Aug-2017**
WHMIS	**Required**		**06-Jan-2016**	**06-Jan-2019**

Note: This report does NOT include optional certificates that are missing or expired.

Employee Certificate List
Brad Mackenzie

Certificate	Compliance	Certificate #	Issue Date	Expiry Date
CN - CP E Rail Safe	**Required**		**26-Mar-2014**	**26-Mar-2017**
Commercial Vehicles	Optional		04-Jan-2016	04-Jan-2019
CSTS	**Required**		**12-Jul-2013**	
Directing Vehicles	**Required**		**Missing**	
Driver Improvement / Defensive Driving	**Required**		**05-Jan-2015**	
Driver's License	**Required**		**23-Oct-2013**	**20-Aug-2016**
Fire Safety	**Required**		**04-Jan-2016**	**04-Jan-2019**
First Aid / CPR	**Required**		**07-Jan-2016**	**07-Jan-2019**
Fit Test SCBA	Optional		03-Mar-2016	03-Mar-2017
Forklift Operator	**Required**		**04-Jan-2016**	**04-Jan-2019**
Ground Disturbance	**Required**		**26-Mar-2014**	**26-Mar-2017**
Hazard Identification and Risk Assesment	Optional		05-Jan-2015	
Hearing Test	**Required**		**06-Jan-2016**	**06-Jan-2017**
Hours of Service	**Required**		**04-Jan-2016**	**04-Jan-2019**
Hydrogen Sulfide (H2S)	Optional	000083 Temp	23-Jun-2015	23-Jun-2018
Imperial Oil RRS	**Required**		**04-Jan-2016**	**04-Jan-2017**
LPS Interim	**Required**		**06-Jan-2016**	**06-Jan-2017**
OSSA/BSO	Optional		25-Jun-2015	
Port Pass	**Required**		**10-Dec-2013**	**10-Dec-2018**
POST	**Required**		**01-Jan-2016**	**01-Jan-2017**
Respirator Fit Testing	**Required**		**06-Jan-2016**	**06-Jan-2017**
Shell Life Saving Rules	**Required**		**04-Jan-2016**	**04-Jan-2017**
Skid Steer Certification	**Required**		**28-Apr-2014**	**28-Apr-2017**
Suncor - Journey to Zero	**Required**		**04-Jan-2016**	**04-Jan-2017**
Transportation Endoresment	**Required**		**08-Jan-2016**	**08-Jan-2019**
Transportation of Dangerous Goods (TDG)	**Required**		**06-Jan-2015**	**06-Jan-2018**
WHMIS	**Required**		**04-Jan-2016**	**04-Jan-2019**
Wildlife Awareness	Optional		07-Jul-2015	

WORK SAFE BC
WORKING TO MAKE A DIFFERENCE

Assessment Department
Mailing Address
PO Box 5350
Station Terminal
Vancouver BC V6B 5L5

Location
6951 Westminster Highway
Richmond BC
V7C 1C6
www.worksafebc.com

Clearance Section
Telephone 604 244 6380
Toll Free within Canada
1 888 922 2768
Fax 604 244 6390

Keystone Environmental Ltd
Suite 320
4400 Dominion Street
BURNABY, BC V5G 4G3

July 06, 2016

Person/Business : MUD BAY DRILLING (2015) LTD.
MUD BAY DRILLING
957885 AQ(014)

We confirm that the above-mentioned account is currently active and in good standing.

This firm has had continuous coverage with us since October 01, 2015 and has satisfied assessment remittance requirements to April 01, 2016.

The next payment that will affect this firm's clearance status is due on July 20, 2016.

This information is only provided for the purposes of Section 51 of the *Workers Compensation Act*, which indicates that a person using a contractor or subcontractor to perform work may be responsible for unpaid assessments of the contractor or subcontractor.

Employer Service Centre
Assessment Department

Clearance Reference # : C129024863
CLRA1A

CERTIFICATE OF INSURANCE

DATE (YY/MM/DD) October 22, 2015

BROKER

envision INSURANCE

This certificate is issued as a matter of information only and confers no rights upon the certificate holder. This certificate does not amend, extend or alter the coverage afforded by the policies below.

INSURED
Mud Bay Drilling (2015) Ltd.
19545 Telegraph Trail
Surrey, British Columbia V4N 4G9

COMPANIES AFFORDING COVERAGE	
COMPANY A	**Intact Insurance Company**
COMPANY B	**Chubb Insurance Company**
COMPANY C	
COMPANY D	

COVERAGES

This is to certify that the policies of insurance listed below have been issued to the insured named above for the policy period indicated, notwithstanding any requirement, term or condition of any contract or other document with respect to which this certificate may be issued or may pertain, the insurance afforded by the policies described herein is subject to all the terms, exclusions and conditions of such policies.

LIMITS SHOWN MAY HAVE BEEN REDUCED BY PAID CLAIMS.

CO LTR	TYPE OF INSURANCE	POLICY NUMBER	POLICY EFFECTIVE DATE (YY/MM/DD)	POLICY EXPIRY DATE (YY/MM/DD)	LIMITS	
A	GENERAL LIABILITY ☒ COMMERCIAL GENERAL LIABILITY ☐ CLAIMS MADE ☒ OCCURRENCE Bodily Injury (Including Disease) & Property Damage Coverage ☒ TENANT'S LEGAL LIABILITY CROSS LIABILITY INCLUDED EMPLOYERS LIABILITY INCLUDED PRIMARY/NONCONTRIBUTORY COVERAGE ☒ NON-OWNED ☐ HIRED	5A1197508	2015/09/24	2016/09/24	EACH OCCURRENCE	$10,000,000.
					GENERAL AGGREGATE	$10,000,000.
					PRODUCTS – COMPLETED/OP AGG	$10,000,000.
					PERSONAL INJURY	$10,000,000.
					TENANT'S LEGAL LIABILITY	$500,000.
					MEDICAL PAYMENTS ANY ONE PERSON	$2,500.
					NON-OWNED AUTOMOBILE	$10,000,000.
					AGGREGATE	
A	CONTRACTORS EQUIPMENT	5A1197508	2015/09/24	2016/09/24	BROAD FORM	$3,000,000.
B	ENVIRONMENTAL LIABILITY	37334702	2015/10/02	2018/10/02	POLLUTION LIABILITY	$5,000,000.

A	ADDITIONAL INSURED	DESCRIPTION OF OPERATIONS/LOCATIONS/AUTOMOBILES/SPECIAL ITEMS **Drilling Investigation** **Intact Insurance A.M. Best Rating = A+**

CERTIFICATE HOLDER

To Whom It May Concern

CANCELLATION

Should any of the above described policies be cancelled before the expiration date thereof, the issuing company will endeavor to mail **30 days written notice** to the certificate holder named to the left, but failure to mail such notice shall impose no obligation or liability of any kind upon the company, its agents or representatives.

AUTHORIZED REPRESENTATIVE – Elaine Stewart, CIP

Elaine Stewart

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This policy contains a clause that may limit the amount payable.

Flowing Artesian Wells

Water Stewardship Information Series

BRITISH COLUMBIA
The Best Place on Earth

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This booklet contains general information on flowing artesian wells for well drillers, groundwater consultants and well owners in British Columbia. The booklet provides general guidelines on flowing artesian wells and does not replace professional knowledge or experience.

What's the difference between a flowing artesian well and an artesian well?

An **artesian well** is a well that taps into a confined aquifer (see Figure 1). Under artesian pressure, water in the well rises above the top of the aquifer, but does not necessarily reach the land surface. A **flowing artesian well** is one that has been drilled into an aquifer where the pressure within the aquifer forces the groundwater to rise above the land surface naturally without using a pump. Flowing artesian wells can flow on an intermittent or continuous basis and originate from aquifers occurring in either unconsolidated materials such as sand and gravels or bedrock, at depths ranging from a few meters to several thousand meters. All flowing wells are artesian, but not all artesian wells are flowing wells.

Why do wells flow?

Flowing artesian wells can be found in two types of situations:

- the aquifer is confined by impermeable materials (i.e., confined beds where the static water level is above the top of the aquifer and land surface); or
- the aquifer is not confined, but the static water level is above the land surface.

Static water level is the level to which water will naturally rise in a well without pumping. For flowing artesian wells, the groundwater level or static water level can be expressed as a head (e.g., artesian head) and reported as a length (feet or meters above ground level) or pressure (pounds per square inch or psi).

Artesian conditions can be generated by geological and topographical controls (see Figure 1) or by topographical controls alone (Figure 2). In the former, water in an artesian well rises upward due to the pressure confined in the aquifer. Artesian wells are found in inclined confined aquifers sandwiched between layers of rock or overburden that are impervious or have low permeability. Water enters the exposed portion of the aquifer at a high elevation and percolates down through interconnected pore spaces. The water held in these spaces is under pressure (confining pressure or hydrostatic head) due to the high elevation from which it originally came. If a well is drilled from the land surface through the overlying impervious layer, the pressure inside the aquifer will cause the water to rise in the well. In areas where the pressure of the aquifer is great enough, the water rises above ground level resulting in a flowing artesian well.

Hydrostatic head (or confining pressure) is the vertical distance between the water level in the well and the top of the aquifer and is expressed in feet or meters of water or pressure (psi).

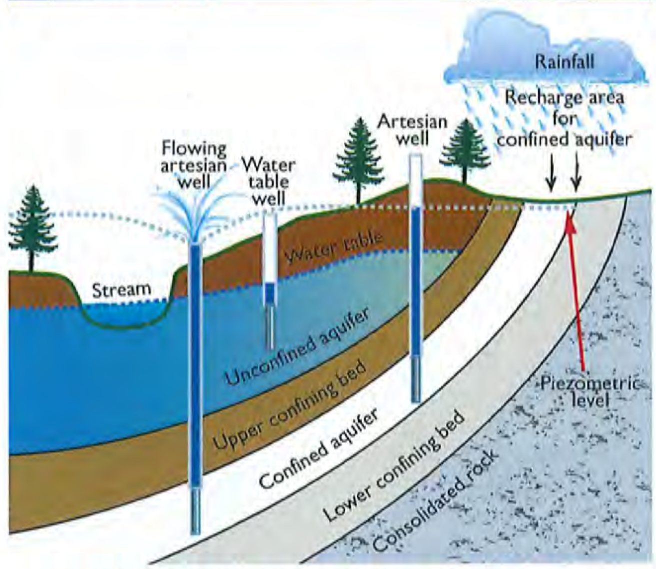

Figure 1. Geological and topographical controls affecting artesian and flowing artesian wells.

Topographical control situations can be found in unconfined aquifers where the well intake is deep enough to intercept a zone where the hydraulic head is higher than the land surface (see Figure 2). This situation typically occurs in groundwater discharge areas at lower elevations near rivers and lakes in valleys surrounded by steep slopes. The pressure of the groundwater typically increases with depth in the discharge areas where the slope of the water's flow path and its pressure are controlled by the topography. As the groundwater moves along the flow path, it can migrate

Hydraulic head is a measurement of the water level or total energy per unit weight above a datum such as sea level. It is commonly measured as water surface elevation in feet or meters.

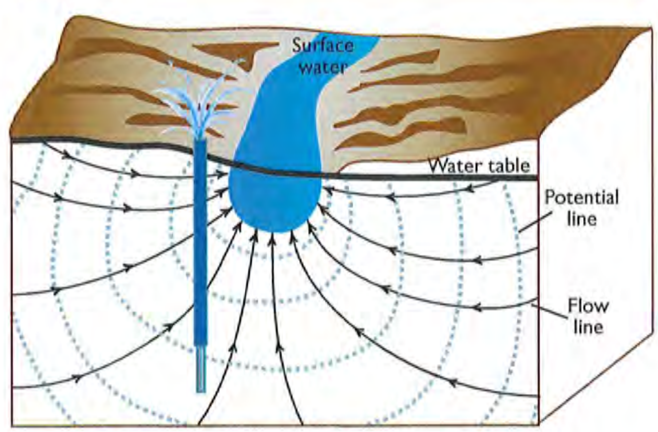

Figure 2. Topographically controlled flowing artesian well.

deep below ground where it can lie beneath shallow non-artesian groundwater. When a well is drilled into a deeper zone of higher hydraulic head, the groundwater can move upwards inside the well casing to a level that is higher than the levels of the land surface, resulting in a flowing artesian well.

Why is stopping or controlling artesian flow important?

Flow from artesian wells should be controlled to prevent wasting groundwater. For instance, an uncontrolled artesian well flowing at 10 USgpm (55 m^3/day) wastes 14,400 USgallons (55 m^3) every day and 5.25 million USgallons (2.0×10^4 m^3) per year. An uncontrolled flow of 1 USgpm wastes enough water to supply four homes. Wasting water may lower the confining pressure in the aquifer so that the well no longer flows or flows at a reduced rate and affects the yield of neighbouring wells and springs.

Figure 3. Erosion caused by flowing artesian well.

When groundwater breaks out on the outside of the well casing, flooding, damage and/or subsidence and sinkhole formation can occur. Another reason to control flow is to prevent groundwater flowing from an aquifer under artesian pressure into an overlying aquifer(s). If the flowing well breakout is not promptly contained, silt, clay, gravel, sand, and drilling fluids can be carried along with the artesian groundwater to the ground surface and eventually reach surface water. The quality of the surface water and the habitat of aquatic organisms can be impacted.

Flowing artesian wells can also cause erosion (see Figure 3). Flowing water that accumulates into ponds can also contribute to mosquito problems.

How can flowing artesian conditions be determined before drilling?

Before a well is drilled, it is important for the person responsible for drilling the well (qualified well driller or qualified professional[1]) to do a pre-drilling assessment to determine the range of pressures and flows that might be found during drilling, i.e., whether flowing artesian conditions are likely to be encountered.

[1] Qualified professionals who are registered with the Association of Professional Engineers and Geoscientists of British Columbia with competency in hydrogeology or geotechnical engineering.

The pre-drilling assessment should include gathering information about geological conditions, static water levels and any history of flowing artesian wells in the area. This information can be obtained from:

- reviewing available local well construction reports;
- reviewing hydrogeologic information (e.g., maps on the Water Resource Atlas http://www.env.gov.bc.ca/wsd/data_searches/wrbc/index.html showing flowing artesian well coverage (see Figure 4) or reports on Ecocat http://www.env.gov.bc.ca/ecocat/);
- consulting with the Ministry of Environment regional hydrogeologists; and
- consulting with well drillers and professional hydrogeologists or geotechnical engineers with knowledge of the local area.

If this information is not available, the person responsible for drilling the well should consider the proposed well depth in relation to relevant topographic and geologic information about the site (i.e., whether the proposed well is going to be deep in a valley-bottom location). Geophysical logs or an electric survey can also be used to better understand subsurface conditions. When knowledge is limited, a precautionary approach should be taken and planning should assume that flowing artesian conditions will be present.

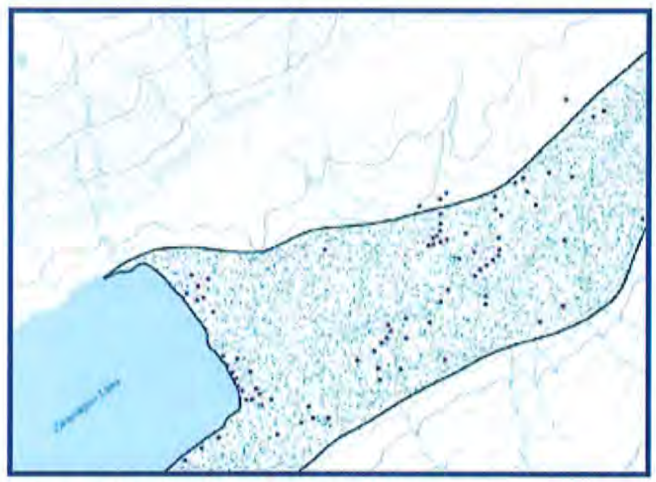

Figure 4. Map from the BC Water Resource Atlas showing provincial mapped and classified aquifers, contoured elevations and wells (purple dots) that were flowing artesian wells at the time drilling.

What are the provincial regulatory requirements for controlling or stopping artesian flow?

The provincial regulatory requirements for controlling flowing artesian wells are outlined in section 77 of the *Water Act*. If artesian conditions are encountered when constructing or supervising construction of a well, the qualified well driller or qualified professional must ensure the artesian flow is or will be stopped or controlled and advise the well owner (and the land owner, if applicable) of the steps taken to do so. It is also good practice to advise of any potential hazards associated with uncontrolled flow not being controlled (e.g., erosion, flooding, subsidence) and any associated costs. Agreement on these issues, prior to drilling can help prevent or minimize misunderstandings. For example, some issues can be addressed in a contract. If the qualified well driller or qualified professional fails to stop or control the flow, it is the well owner's responsibility to hire another qualified professional or qualified well driller to ensure that the flow is stopped or controlled. If the ownership of the well is not known, the land owner is responsible to have this done. If the flow cannot be controlled, the person responsible for drilling the well should advise the Ministry of Environment's regional hydrogeologist and must comply with any direction given.

A flowing artesian well must have a securely attached cap to provide access to the well, prevent entry of vermin and contaminants, and to prevent flow escaping from the well.

What does it mean to "control" artesian flow from a well?

A flowing artesian well is considered "under control" when the entire flow is through the production casing to the wellhead and the flow can be stopped indefinitely without leaking on the surface of the ground and with no leakage into any other aquifer penetrated by the well.

Will a flowing artesian well dry up if the flow is stopped or controlled?

Controlling the flow from a flowing artesian well should not stop the flow or dry up the well if the well has been properly constructed. In fact, the opposite is true as waste of artesian water will often eventually cause a decrease in artesian pressure. Controlling the flow from a flowing artesian well prevents unnecessary loss of groundwater from the aquifer upon which other wells rely.

Are there any water quality concerns with flowing artesian wells?

In general, the water quality of flowing artesian wells is excellent. However, some artesian waters may be very poor quality and cause serious damage on the surface or contaminate an overlaying aquifer. In general, water quality can be affected by the depth of the well, i.e., a deeper flowing artesian well may have poorer water quality than a shallower flowing well. Water from bedrock formations, such as deep sandstone formations, may contain concentrations of arsenic that could pose a health concern. Artesian wells with poor quality water should be permanently closed (see page 8).

Are there any other concerns with flowing artesian wells?

Most of the problems associated with flowing artesian wells result from improper discharge controls or improper well construction.

Casing corrosion (see Figure 5) and leakage can occur due to the constant flow of water, particularly if the water is corrosive

Figure 5. Corroded well casing.

or contains fine sand. Where artesian water is known to be corrosive, a smaller diameter flow pipe may be installed in the well. The pipe may be made of corrosion-resistant material or may be periodically replaced when it becomes corroded. Where the casing has been damaged, a slightly smaller diameter casing can be installed inside the old casing using packers if there is an existing surface seal and sealed in place with a cement grout. It is recommended to have the flowing artesian well checked periodically by a qualified well driller to verify the integrity of the well casing and to inspect the well screen, as the well can be difficult to repair once the casing has been corroded or breached. Thin-wall casing should not be used in flowing artesian wells.

Failure of the casing/surface seal during construction or decades after well completion can be costly and may result in the eruption of large volumes of silt, sand, clay or gravel, causing unstable conditions and potential flooding, damage to nearby structures through erosion and subsidence and harm to the habitat of aquatic organisms.

Well screens for flowing artesian wells can yield water with sand or become plugged with sand if the well is not properly developed. This is an issue when a flowing artesian well in a fine-grained aquifer is shut off and the sand settles and clogs the area in and around the bottom of the casing. The screen size should be coarse enough to prevent pressure build-up in the aquifer and the well should be properly developed. Perforated casings for flowing artesian wells are not recommended. In some areas an unpleasant rotten egg smell (hydrogen sulphide gas) may be present and by reducing or stopping the artesian flow the smell can be brought under control.

What can be done with an existing flowing well?

Trying to stop or control the flow from older flowing wells may result in an uncontrolled discharge of water outside the well casing or at a distance from the well due to the lack of an adequate seal, a defective surface seal or corroded casings. If water does not appear to be flowing outside of the outer casing, then it may be advisable to leave the well alone and not restrict the flow. However, if water appears to be flowing outside the casing and/or the well is causing property or environmental damage, then the well should likely be closed. Alternatively, it may be possible to lower the water levels using a pump but care must be taken to keep the water flowing from the well relatively continuously to avoid additional uncontrolled discharge from occurring.

There are numerous special measures that may be applicable to controlling the flow of an existing flowing artesian well such as using well packers or a bridge to restrict the flow in the confining layer, adding polymers or plasticizers to keep the grout together during placement, using barite to reduce the confining pressure of the water, etc.

Any alteration to an existing flowing well to control the flow needs to be done in compliance with the *Water Act* and Ground Water Protection Regulation and any directions of a Ministry of Environment hydrogeologist. A qualified well driller or qualified professional must be hired. Before any work is done, the well owner should be made aware of the costs and complexities of the work involved with controlling the flowing artesian well, as well as the chances of successfully controlling the flow.

What if the flow is needed, for example, to increase the baseflow of a creek or stream?

In some instances, artesian flow is used to maintain water levels in ponds used for irrigation, fire protection, fish rearing, recreation or wetland enhancement. For existing wells, flow is permissible as long as property is not damaged and streams or aquatic habitats are not negatively impacted. If damage does or may occur, contact the local Ministry of Environment office (see back cover of this booklet).

Are there some general guidelines for constructing a flowing artesian well?

In constructing a well under flowing artesian conditions the potential pressure and flow and the permeability of the formation need to be taken into consideration. A pre-drilling assessment of local conditions may provide this information. If these conditions are known, the following provides general guidance for the design and construction of the well. If this information is not known the well should be designed conservatively for worse case conditions. Flowing artesian wells should not be constructed if the formation conditions are not favourable, i.e., in shallower situations where there is no suitable formation to seal into.

Green Zone (<5 psi)

If the pressure is or will be less than 5 psi (pounds per square inch), flow can usually be controlled by adding additional casing, except where permeability of the formation is extremely high, e.g., medium to coarse gravel. To determine the artesian head use the following conversion factors: 2.31 feet equals 1 psi, and one foot equals 0.3048 meters. For example, for a flowing well with 5 psi, there will be 11.6 ft or 3.5 meters of artesian head, therefore the casing would need to be extended more than 3.5 meters above the ground surface to contain all the artesian head. In general, a 30 per cent bentonite grout can be used for flowing well construction or repair.

Artesian head is the hydraulic pressure created within the confined aquifer that drives the water upward in a well to the piezometric level. The distance from the ground surface to the piezometric level, converted into equivalent pressure (expressed as pounds per square inch, or PSI), is the artesian head.

Yellow Zone (5 to 10 psi)

If the pressure is or will be between 5 and 10 psi, extending the well casing may reduce flow, but extreme care must be taken in highly permeable formations that produce significant volumes of water. Flows of 20 USgpm can potentially occur in this zone and the upward annular velocity resulting from this flow is high enough to begin separating grout mixtures as they are being pumped down. When the pressure is high and the formation highly permeable, it is recommended that an outer surface casing be installed before the permanent casing. The outer casing should end in the confining layer and should not penetrate the underlying artesian aquifer. Cement-type grout should be used.

Red Zone (>10 psi)

If the pressure is or will be greater than 10 psi, static head control or extending the well casing is not usually possible, especially in highly permeable, high-yielding formations. In this category the flow is great enough to make the grout placement very difficult. An outer casing or multiple casings should be installed before the production casing and set to the confining layer so the production casing can be cemented within the outer casing. Cement or cement plus barite (or other weighting additives) should be used as grouting materials.

What are the key issues to be aware of when drilling a flowing artesian well?

Flowing artesian wells under high pressure and with high flow rates (yellow and red zones) are challenging to construct. Flowing wells that are drilled deep (≥200 feet or ≥60 meters) in unconsolidated deposits or drilled into bedrock are less prone to flow problems and are generally easier to deal with. In bedrock environments (see page 7 for more information on bedrock wells), the competent rock allows for easier installation of the seal (i.e., no casing to wash out or concerns about an eroded annulus).

Drilling a well into a confined aquifer disturbs the overlying geologic confining layer and provides a potential pathway for the upward movement of the pressurized artesian water. Well construction must include restoring any damage to the confining layer. In general, the closer the top of the artesian formation is to the ground surface and the higher the pressure, the more difficult it is to control the flow.

In certain conditions (e.g., soft clay/silt formations), the formation will squeeze back in and set up around the well casing over a period of time. If this condition is likely to occur, it is advisable to let the well flow for a week or two to give the formation a chance to settle in before stopping or controlling the flow. This will result in a seal around the casing at deeper depths than the surface seal.

It is good practice for the qualified well driller to observe the condition of the flowing artesian well head for one or two weeks after construction and check for leakages outside the surface casing or between casings.

Materials and Equipment

One of the key factors to successfully controlling the flow is being prepared with the right tools and materials at the job site. Suggested materials and equipment include:

- drilling mud and additives of sufficient weight to deal with the pressures in the aquifer,
- surface and production casing appropriate to the water quality and geological conditions,
- grouting and sealing materials appropriate to the artesian pressure and anticipated flow,
- tremmie pipes,
- pumps suitable for delivering the grouting and sealing materials,
- well screens with adequate transmitting capacity,
- valves,
- inflatable packers,
- surge block, and
- shale traps.

Drilling Muds

To determine the extra weight of drilling mud needed to counteract the pressures of the artesian aquifer during rotary drilling, the estimated artesian head and the depth to the top of the aquifer is needed. The following formula can be used to estimate the additional weight of drilling mud needed to control the flow during the drilling process:

$$\text{Additional mud weight} = \left(\frac{8.34\ \text{lbs/USgal} \times \text{height of water above ground level (ft)}}{\text{Depth to top of aquifer (ft)}}\right) + 0.4\ \text{lbs/USgal}$$

Where:
One USgallon of water weighs 8.34 pounds
0.4 lbs/USgallon is a safety factor

Example

If the depth to the top of the aquifer is 75 feet and the height of water above ground is estimated to be 10 feet, the additional weight of drilling mud needed would be $(8.34 \times 10/75) + 0.4 = 1.5$ lbs/USgal.

Properly mixed, fresh drilling mud will normally weigh about 9 pounds per US gallon. Drilling mud can be made heavier by adding drilling clay, drilling gel and special solids such as barite. However, some drilling gels are treated with polymers to build viscosity and become difficult to pump before their weight significantly increases. Therefore, some drilling gels have limited ability for control of flows. Mud weights of up to 15 pounds per gallon can be achieved using weighting materials such as powdered barite.

Well Casings

Generally, in areas where flowing artesian conditions are known or suspected, at least one outer surface casing should be installed before installing the permanent/production casing or liner to allow for better control. It is not advisable to pull the surface casing within 20 feet (6 meters) of ground surface. Doing so may disturb the seals and cause water to flow around the surface casing as it is pulled, especially if bentonite is used. There should be at least a 4-inch (10 cm) gap or annulus between the outer surface casing and the production casing to allow for the insertion of a tremmie pipe to pump adequate grout volumes For example, if a 6-inch production casing is needed, a 14-inch outer surface casing would have to be installed to provide a 4-inch annulus.

In areas where the pressure is > 5 psi and the formation is highly permeable, a 4 to 6-inch (10 to 15 cm) annulus between the surface and permanent casing is recommended. Ensuring there is an adequate annulus is especially important where formations are highly permeable and high-density grout mixtures are required to adequately control the artesian flow.

Grouting Mixtures

Use of appropriate grouting material is key to constructing a flowing artesian well. Table 1 is useful for finding the hydrostatic head pressure (in psi) and for understanding the relationship between drilling fluid or grout density and their ability to successfully control the flow during drilling, plugging, or repair. Table 1 shows that heavy grouts, such as neat cement/bentonite slurry or cement slurry with additives, have a distinct advantage for flowing well work. Mixing neat cement with bentonite is recommended to avoid cracks from occurring.

It is important to allow for sufficient time for the cement or cement grout mixture to set before proceeding with drilling. Use of the appropriate drilling method to minimize impacting the integrity of the seal is also important. In addition, the flowing artesian well should be gradually sealed or shut-in to prevent rupturing the seal(s).

TABLE 1
TOTAL PRESSURE ABOVE TOP OF CONFINED AQUIFER (HYDROSTATIC PRESSURE) FOR FLOWING ARTESIAN WELLS

Depth to Top of Flowing Aquifer (feet)	Artesian Head Above Ground Surface (feet)					
	5	10	15	20	25	30
10	6.5	8.7	10.8	13.0	15.2	17.3
20	10.8	13.0	15.2	17.3	19.5	21.7
30	15.2	17.3	19.5	21.7	23.8	26.0
40	19.5	21.6	23.8	26.0	28.1	30.3
50	23.8	26.0	28.1	30.3	32.5	34.6
75	34.6	36.8	39.0	41.1	43.3	45.5
100	45.5	47.6	50.0	52.0	54.1	56.3
125	56.3	58.4	60.6	62.8	65.0	67.1
150	67.1	69.3	71.4	73.6	75.8	78.0
175	78.0	80.1	82.3	84.4	86.6	88.7
200	88.7	91.0	93.1	95.2	97.4	99.6
225	99.6	101.7	104.0	106.0	108.2	110.4
250	110.4	112.5	115.7	117.0	119.0	121.2

Adapted from the Michigan Department of Environmental Quality, Water Bureau, Lansing, Michigan

Material	Weight	Hydrostatic Pressure
Barite Slurry:	18 - 22 lb/USgal	.96 - 1.1 psi/ft
Neat Cement and Bentonite @ 6 gal water/sack:	15.0 lb/USgal	.78 psi/ft
Bentonite Slurry Grout:	10.4 lb/USgal	.54 psi/ft
Bentonite Slurry Grout:	9.5 lb/USgal	.49 psi/ft

GROUTING MATERIAL SUITABILITY

	Heavy Enough To Overcome Hydrostatic Pressure	Not Heavy Enough To Overcome Hydrostatic Pressure
(dark shading)	Neat Cement @ 15 lb/USgal	All Bentonite Grouts
(light shading)	Neat Cement @ 15 lb/USgal or Bentonite Grout @ 10.4 lb/USgal	Bentonite Grouts lighter than 10.4 lb/USgal
(no shading)	All standard grouts have enough weight to overcome hydrostatic pressure of the flow.	

The values in Table 1 correspond to the downhole head pressure (in psi) for different scenarios, e.g., if the depth to the top of the aquifer was 10 feet and the artesian head was 5 feet, the downhole head pressure will be 15 feet or 6.5 psi. To overcome the flow, the downhole grout pressure must be greater than the downhole head pressure.

The following example illustrates how Table 1 can be used to select drilling fluids or grout that are heavy enough to control the flow during drilling.

Example of how to use Table 1

Q. *The top of an artesian aquifer is found at 50 feet and wells in the area have about 15 feet of artesian head. What minimum weight drilling fluid would be needed to overcome the hydrostatic pressure during drilling?*

A. The following steps are used to solve the problem:

Step A: To determine the downhole hydrostatic head pressure look at **Table 1** and find the cell corresponding to depth of top of aquifer (50 ft) and artesian head (15 ft) which is 28.1 psi. This pressure represents the total head above the top of the confined aquifer (e.g., 15 + 50 = 65 ft or 28.1 psi).

Step B: Divide the downhole hydrostatic pressure (28.1 psi) by the depth to the top of the aquifer (50 ft) to determine the downhole grout pressure needed to equalize the flow (28.1 psi/50 ft = 0.56 psi/ft).

Step C: To determine the grout weight divide the downward pressure of the grout (0.56 psi/ft) by 0.052 (a factor to convert lb/USgal to psi/ft of depth). The minimum grout weight needed to control the flow is 10.8 lb/USgal.

Are there specific actions to avoid when flowing artesian conditions are present?

When a large volume, high pressure flow breaks out, the immediate situation can be serious and there is usually a concern to quickly move the drilling rig away from the borehole. Hastily made decisions can get in the way of successful future corrective actions. As up-flowing artesian water typically will erode fine sediments around a solid object that has been placed loosely below ground, the following actions should be avoided:

- dumping field stone or gravel into the annulus around the well casing as this can prevent the installation of grout pipes or a larger casing into the borehole and can collapse PVC well casing;
- pouring ready-mix concrete or bentonite chips into the annulus as it is likely that the concrete or bentonite will solidify above the depth where the flow is originating and

result in a plug that causes the flow to wash out around its perimeter; or

- jamming unopened bags of cement, bentonite chips, lumber, cardboard or other debris into the washed out annulus as these materials are ineffective and complicate further corrective action.

How can flowing artesian wells be constructed in bedrock aquifers?

When constructing an artesian well that is likely to flow in a **bedrock aquifer**, the final or outer well casing should be sealed at least 10 feet (0.3 meters) into competent bedrock. Figure 6 shows one possible method of completing a flowing artesian well in bedrock. Construction techniques and choice of sealant materials need to be determined by the qualified well driller based on site specific conditions, e.g., pressure and flow.

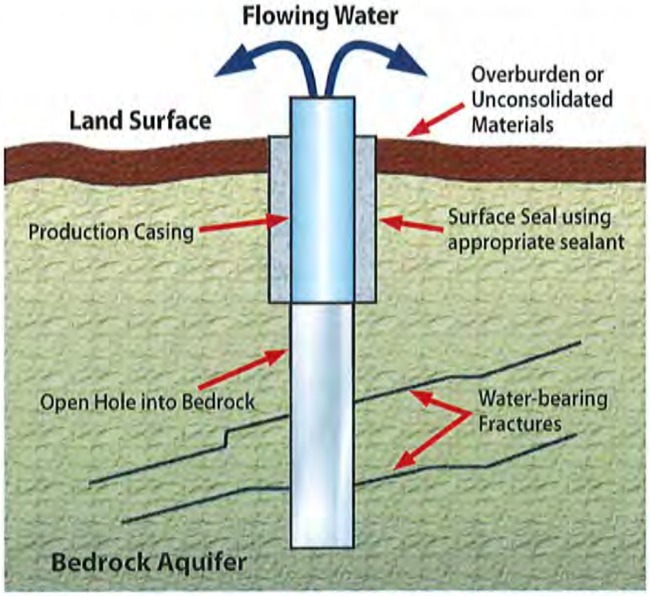

Figure 6. One possible method of completing a flowing artesian well in a bedrock aquifer.

How can flowing artesian wells be constructed in unconsolidated aquifers?

For **confined, unconsolidated aquifers** where flowing artesian conditions are likely, a cased oversized hole should be drilled into the confining layer, to allow a cement, or high solids bentonite seal to be placed between the final production casing and the outer casing (see Figure 7). This can be very complicated and expensive if the pre-drilling assessment indicates the confining layers are more than 100 ft (30 metres) deep. The size of the hole or casings and the depth of the seal must be determined on a site-by-site basis since choices are influenced by local geology and the specific artesian conditions encountered. A careful, conservative approach is recommended.

Figure 7. Bentonite cement grout seal between casings.

When constructing a well into a confined, unconsolidated flowing artesian aquifer, the appropriate sealant material between the outermost well casing and the confining layer must be of a sufficient depth and thickness to contain the flow.

Artesian conditions in **unconfined, unconsolidated aquifers** require special construction techniques such as using heavier drilling mud to counteract the pressure of the aquifer and a temporary surface casing to prevent hole collapse.

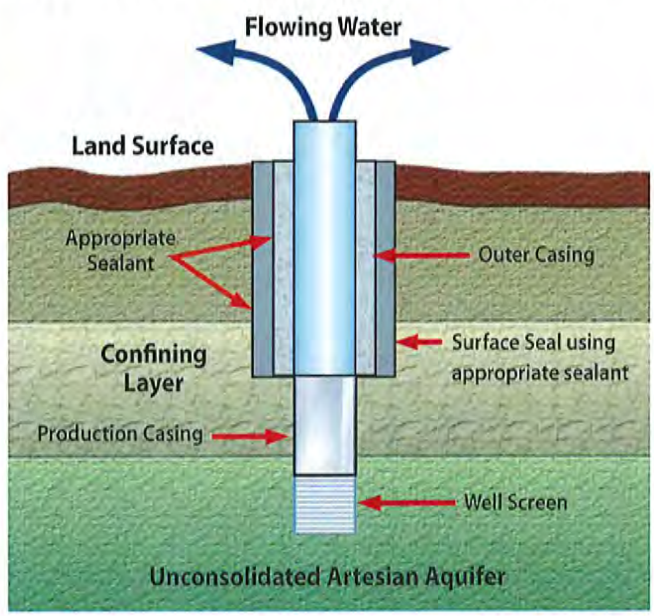

Figure 8. One possible method of completing a flowing artesian well in unconsolidated materials, e.g., sand and gravels.

What should be done if flowing artesian conditions are suddenly encountered?

When unexpected flowing artesian conditions are encountered (i.e., instant flow occurs), a qualified professional, or qualified well driller, should take control of the site and equipment should not be removed from the site until the artesian flow is under control. Contact the owner of the well and the land owner immediately to report the situation and provide plans to control the flow (see below). Steps to take include:

- control the flow,
- secure the casing or borehole, and
- protect the drill rig.

The flow may be brought under control by:

- increasing the weight of the drilling mud,
- using plugs,
- using a surge-blocking to restrict flow, or
- installing a drillable packer.

The drill pipes can be left in place in cases where the uncontrolled flow occurs in an uncased drill hole, to indicate the exact location of the hole.

If the flowing artesian well is discharging water into a wetland or surface water body, contact the local Ministry of Environment office.

It is important for the well owner (and land owner if applicable) to develop a clear understanding, potentially in the form of a contract, with the drilling contractor on how the well will be repaired and/or the flow stopped or controlled before any work on the well commences to avoid or minimize potential misunderstandings when artesian flow is encountered.

What are the key factors in completing and equipping a flowing artesian well?

Flowing artesian wells, when properly constructed, should be equipped with a device to completely stop or control the artesian flow from the well (see Figure 9). After flow is stopped, there should be no leakage up the annulus between the outermost casing and the borehole. If water does escape, the annulus should be sealed.

Figure 9. Completed high pressure flowing artesian well.

Flowing artesian wells, like all wells, need to be vented. Well caps should be equipped with a two-way vent that allows the well to inhale and exhale air as the water level changes during pumping cycles. The vent will seal the well when the pump is not in use.

Determine the shut-in pressure (see below) and record the measurement on the well construction report. The wellhead should also be designed and equipped to prevent any backflow into the well.

Where freezing conditions may occur, the wellhead of the new flowing artesian well should be covered, insulated and heated, where necessary, to prevent damage of the flow control device leading to an uncontrolled flow situation.

How is the pressure or static water level for a flowing artesian well measured?

It is important to determine and record the hydrostatic pressure of the flowing artesian well for future pre-drilling assessments. There are several ways to measure the hydrostatic pressure or static water level of a flowing artesian well:

1. Extend the well casing, or a smaller diameter pipe through a well seal on the top of the casing, high enough above the ground surface until water no longer flows out the top (without pumping). The water level in the casing extension can then be measured using a water-level sounder. The distance from the piezometric water level in the casing to the ground surface is the artesian head of the aquifer – this can be converted to pressure.

2.31 feet equals 1 psi or
0.433 psi equals 1 foot

Example

A static water level of 30 feet is converted to pressure by dividing 30 feet by 2.31 feet/psi = 13 psi.

2. A pressure gauge installed on a well seal at the top of the casing will provide the pressure reading which can be multiplied by 2.31 to find the artesian head at the gauge elevation.

How should flowing artesian wells be closed?

A qualified well driller and/or qualified professional should be hired to close a flowing artesian well and ensure that the well is closed in such a manner that there is no leakage at the surface of the ground (see Figure 10). The driller must be prepared to handle the flow from the well and the discharge of any plugging materials immediately on removal of the flow control device(s). The work site can be dangerous if the flow is not properly diverted. Closing a flowing artesian well is simplified if the flow can be overcome by extending the well casing above the artesian head. Alternatively, insert an inflatable packer or expandable rubber plug at the bottom of the casing. Physically stopping the flow may make things worse, however, which is why the rapid loading of drilling gel is often a better approach.

Another effective approach is lowering the water level by pumping from adjacent wells. A leaking annulus should be sealed (if possible) before proceeding with grouting the production casing.

Pump a high density grout such as neat cement or concrete grout with bentonite through a PVC pipe or drill rod which is lowered to the bottom of the well. The cement mixture is pumped until it reaches the land surface. Pressure grouting with a packer may be required. It may also be good to pull or perforate some of the casing to allow the grout to flow from the casing into the annulus, although this is not critical if the casing is already perforated or corroded.

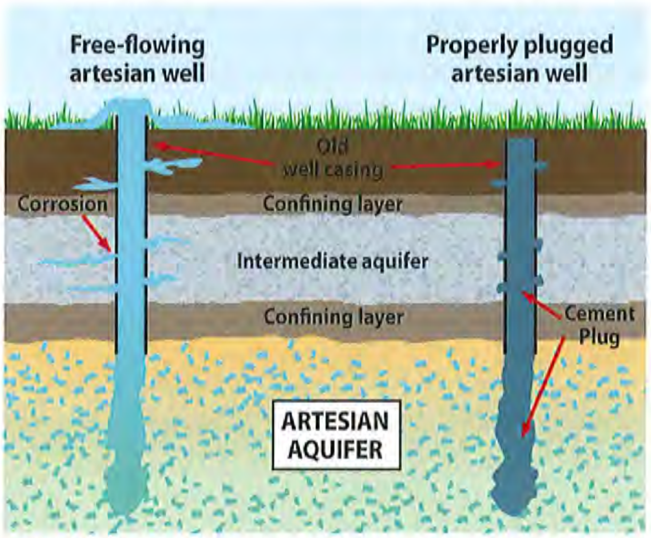

Figure 10. Example of a properly closed flowing artesian well.

How is a flowing artesian well disinfected?

Because of the protected nature of the confined artesian aquifer, flowing wells are generally less prone to bacterial contamination. Furthermore, the positive artesian pressure can minimize entry of surface contaminants into the well. Contamination introduced during the drilling process may be flushed out by the continuous discharge of water.

To disinfect a flowing well using chlorine, a temporary casing extension above the piezometric level or a tight well cap or seal can stop the flow and increase the chlorine contact time. A chlorine solution can also be pumped into the well via the secure well cap and hose connections. Once the casing extension or cap is removed, the well discharge will flush residual chlorine and inactivated bacteria from the well.

If the chlorinated water has a potential to harm the environment (e.g., fish), use an effective neutralizing agent, such as Vitamin C, to inactivate the chlorine. A solution of at least 1 per cent (by weight) of ascorbic acid is the most cost-effective form of Vitamin C. Added to the sump or a stream of chlorinated water, reaction time is nearly instantaneous.

Further Information

A registry of qualified well drillers can be found at: http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/wells/applications/well_drillers_reg.pdf.

A listing of groundwater consultants (qualified professionals) can be found at: http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/library/consultants.html.

Michigan Department of Environmental Quality, 2005. Flowing well handbook: http://www.michigan.gov/documents/deq/deq-wb-dwehs-wcu-flowwellhandbook_221323_7.pdf.

For further information on whether approvals are needed for discharging flowing artesian well water to surface water bodies, contact the local Ministry of Environment office:

Vancouver Island Region....................	Nanaimo	250-751-3100
Lower Mainland Region........................	Surrey	604-582-5200
Thompson and Cariboo Regions...........	Kamloops	250-371-6200
Kootenay and Okanagan Regions............	Nelson	250-354-6333
	Penticton	250-490-8200
Omineca Peace and Skeena Regions	Prince George	250-565-6135

BRITISH COLUMBIA
The Best Place on Earth

Ministry of Environment

The British Columbia Ground Water Association

Photos by Jim Fyfe, David Martin, Mike Simpson, Peter Epp & Thierry Carriou.
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TOPOGRAPHIC PLAN OF LOTS 1 AND 2, BLOCK A, DL 686, PLAN 14197, AND LOTS 1 AND A, DL 685, PLAN 5579

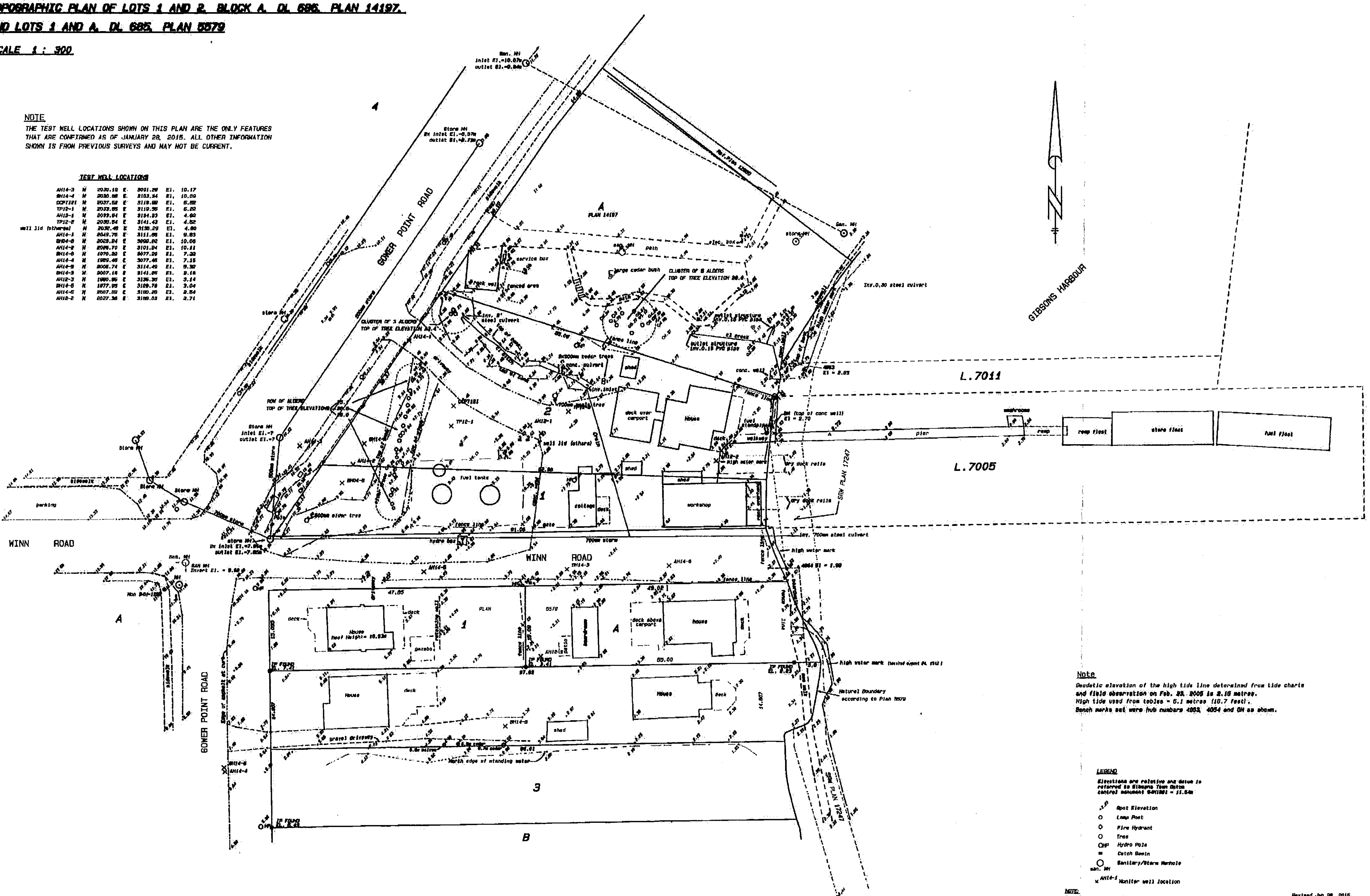
SCALE 1 : 300

NOTE

THE TEST WELL LOCATIONS SHOWN ON THIS PLAN ARE THE ONLY FEATURES THAT ARE CONFIRMED AS OF JANUARY 28, 2015. ALL OTHER INFORMATION SHOWN IS FROM PREVIOUS SURVEYS AND MAY NOT BE CURRENT.

TEST WELL LOCATIONS

AH14-3	N	2030.10	E	3091.20	El.	10.17
BH14-4	N	2030.08	E	3103.34	El.	10.09
DCPT121	N	2037.62	E	3110.82	El.	6.82
TP12-1	N	2033.65	E	3110.56	El.	6.82
AH12-1	N	2099.04	E	3134.83	El.	4.02
TP12-2	N	2039.64	E	3141.43	El.	4.82
well lid (others)	N	2032.48	E	3158.29	El.	4.80
AH14-1	N	2049.76	E	3111.66	El.	9.83
BH04-8	N	2023.24	E	3090.82	El.	10.06
AH14-2	N	2026.70	E	3101.24	El.	10.11
BH14-6	N	1970.22	E	3077.20	El.	7.32
AH14-4	N	1989.46	E	3077.46	El.	7.15
AH14-5	N	2005.74	E	3114.49	El.	5.32
BH14-3	N	2007.14	E	3141.86	El.	3.18
AH12-3	N	1980.86	E	3136.36	El.	3.14
BH14-5	N	1977.95	E	3129.78	El.	3.04
AH14-6	N	2007.82	E	3180.28	El.	2.84
AH12-2	N	2027.36	E	3169.03	El.	2.71



Note

Geodetic elevation of the high tide line determined from tide charts and field observation on Feb. 23, 2005 is 2.16 metres.
High tide used from tables = 5.1 metres (16.7 feet).
Bench marks set were hub numbers 4053, 4054 and OH as shown.

LEGEND

Elevations are relative and datum is referred to Gibsons Town Datum control monument 94H1801 = 11.54m

- Spot Elevation
- Lamp Post
- Fire Hydrant
- Tree
- Hydro Pole
- Catch Basin
- Sanitary/Storm Manhole (san. MH)
- AH14-1 Monitor well location

NOTE:
Diameters of pipes shown were determined from data from the Town of Gibsons and from field inspection which was hampered by high volumes. A further inspection is required for any costruction design.

Revised Jan 28, 2015.
Revised Aug 26, 2013.
OCTOBER 5, 2012
504T - 1504

Larry N. Penonzek
B. C. Land Surveyor
Box 905 Gibsons, B.C.
V0N 1V0 Fx. 886-2553
Phone 604-886-2531

SAN MH
LID EL. 6.07
Invert El. 4.82

Subsurface Disturbance Type (use dropdown menu)	Method of exploration (use dropdown menu)	Number (Test Pit, Well, borehole, etc…)	Zone	Northing (m)	Easting (m)	Ground Elevation (m amsl)	Proposed testing depth below ground (m)	Previously Encountered Depth to top of Gibsons Aquitard (ie: Till-Like Soil (m))	Previously Encountered Depth to top of Gibsons Aquifer (ie: Sand and gravel with Artesian flow (m))	Distance of existing subsurface information to proposed new intrusive work (m)	Report Reference for previous work to support new proposed work (Copies of original logs/records should be attached)	Estimated depth offset to top of Gibson Aquitard (m, + if above and - if below)	Estimated depth offset to top of Gibson Aquifer (m, + if above and - if below)	Comment on uncertainty and potential risk to aquifer	Describe Aquifer Protection measures to be implemented
Hand Excavation	Hand or tube surface sample	SED-A	10U	5472041	463216	0	0.3	3.4	6.4	45	Horizon Report 2014	3.1	6.1	Existing data far from new location, heterogenous soils, subsurface disturbace not expected to breach aquitard, risk is juded to be low	Monitor groundwater upwelling, EC
Hand Excavation	Hand or tube surface sample	SED-B	10U	5472052	463207	0	0.3	3.4	6.4	50	Horizon Report 2014	3.1	6.1	Existing data far from new location, heterogenous soils, subsurface disturbace not expected to breach aquitard, risk is juded to be low	Monitor groundwater upwelling, EC
Hand Excavation	Hand or tube surface sample	SED-C	10U	5472042	463198	0	0.3	3.4	6.4	55	Horizon Report 2014	3.1	6.1	Existing data far from new location, heterogenous soils, subsurface disturbace not expected to breach aquitard, risk is juded to be low	Monitor groundwater upwelling, EC
Piezometer	Drive Point	SV-1	10U	5472021	463134	11	1.7	2.9	3.7	12	Horizon Report 2014	1.2	2.0	Existing data far from new location, heterogenous soils, subsurface disturbace not expected to breach aquitard, risk is juded to be low to moderate	Monitor groundwater upwelling, EC. Excavate out and seal boring with bentonite if artesian conditions encountered. Monitor backfilled excavation for indications of weeping.
Piezometer	Drive Point	SV-2	10U	5472031	463133	12	1.7	2.9	3.7	22	Horizon Report 2014	1.2	2.0	Existing data far from new location, heterogenous soils, subsurface disturbace not expected to breach aquitard, risk is juded to be low to moderate	Monitor groundwater upwelling, EC. Excavate out and seal boring with bentonite if artesian conditions encountered. Monitor backfilled excavation for indications of weeping.
Test Pit	Backhoe	TP-A	10U	5472033	463205	0	1.5	3.4	6.4	50	Horizon Report 2014	1.9	4.9	Existing data far from new location, heterogenous soils, subsurface disturbace not expected to breach aquitard, risk is juded to be low	Monitor groundwater upwelling, EC
Test Pit	Backhoe	TP-B	10U	5472020	463214	0	1.5	3.4	6.4	50	Horizon Report 2014	1.9	4.9	Existing data far from new location, heterogenous soils, subsurface disturbace not expected to breach aquitard, risk is juded to be low	Monitor groundwater upwelling, EC
Test Pit	Backhoe	TP-C	10U	5472021	463200	0	1.5	3.4	6.4	60	Horizon Report 2014	1.9	4.9	Existing data far from new location, heterogenous soils, subsurface disturbace not expected to breach aquitard, risk is juded to be low	Monitor groundwater upwelling, EC
Test Pit	Backhoe	TP-D	10U	5472022	463189	0	1.5	3.4	6.4	70	Horizon Report 2014	1.9	4.9	Existing data far from new location, heterogenous soils, subsurface disturbace not expected to breach aquitard, risk is juded to be low	Monitor groundwater upwelling, EC
Test Pit	Backhoe	TP-E	10U	5472036	463176	7	2.7	2.9	3.7	37	Horizon Report 2014	0.2	1.0	Existing data far from new location, heterogenous soils, subsurface disturbace not expected to breach aquitard, risk is juded to be low to moderate	Excavate with caution and monitor groundwater ingress, EC. If artesian conditions encountered, re-seal aquitard with bentonite, backfill to surface. Monitor pit location for weeping.
Test Pit	Backhoe	TP-F	10U	5472018	463117	12	2.7	2.9	3.7	25	Horizon Report 2014	0.2	1.0	Existing data far from new location, heterogenous soils, subsurface disturbace not expected to breach aquitard, risk is juded to be low to moderate	Excavate with caution and monitor groundwater ingress, EC. If artesian conditions encountered, re-seal aquitard with bentonite, backfill to surface. Monitor pit location for weeping.
Test Pit	Backhoe	TP-G	10U	5472024	463118	12	2.7	2.9	3.7	25	Horizon Report 2014	0.2	1.0	Existing data far from new location, heterogenous soils, subsurface disturbace not expected to breach aquitard, risk is juded to be low to moderate	Excavate with caution and monitor groundwater ingress, EC. If artesian conditions encountered, re-seal aquitard with bentonite, backfill to surface. Monitor pit location for weeping.
Monitoring Well	Core	MW-A	10U	5472019	463128	12	3	2.9	3.7	18	Horizon Report 2014	-0.1	0.7	Existing data far from new location, heterogenous soils and lack of thick confining layer, subsurface disturbace potential to breach aquitard, encroaching on aquifer, risk is juded to be moderate to high	Drill with sealed surface casing to maintain well control. Re-seal aquitard with bentonite, and seal entire length of boring to surface. Any well install to be completed in separate borehole.