Ontario

Water Supply Wells: Requirements and Best Practices

This manual provides a clear and concise discussion of Regulation 903 as amended under the *Ontario Water Resources Act R.R.O. 1990* (The Wells Regulation). It also provides best management practices and recommended techniques that help a person constructing a well to go beyond the minimum standards set by the Wells Regulation and better protect and minimize adverse impacts to our environment.

Revised April 2015

Note: The numbers and details presented in this manual are current as of the date of publication. Any new regulation or legislation that has been written or revised following this date takes precedence over what is stated here.

Cette publication hautement spécialisée n'est disponible qu'en anglais en vertu du règlement 671/92, qui en exempte l'application de la *Loi sur les services en français*. Pour obtenir de l'aide français, veuillez communiquer avec le ministère de l'Environnement et Action en matière de changement climatique au où .

Master Table of Contents

1. Introduction

Purpose

The intention of this manual is two-fold. First, it provides quick access to a simplified, clear and concise discussion of *Regulation 903* of the Revised Regulations of Ontario, 1990 (Wells) made under the *Ontario Water Resources Act* R.R.O. 1990 (The *Wells Regulation* [1]). Second, it provides best management practices and recommended techniques that help a person constructing a well to go beyond the minimum requirements set by the *Wells Regulation*. In this manual, best management practices are recommended actions or steps that exceed the minimum regulatory requirements to better protect the groundwater and the natural environment. If there are any discrepancies between this guidance and the *Wells Regulation*, the *Wells Regulation* and the *Ontario Water Resources Act* takes precedence.

This manual covers requirements and best management practices for water supply wells. Examples of water supply wells include public, domestic, livestock, irrigation, industrial, municipal, and earth energy system (groundwater source) wells.

The best management practices presented in this manual are intended to provide a practice or combination of practices based on research, field-experience, and expert review, which are both effective and practical for water supply wells. A separate manual for test holes and dewatering wells titled Test Holes and Dewatering Wells – Requirements and Best Management Practices has been prepared by the Ministry of the Environment and Climate Change that covers requirements and best management practices for a “test hole” and a “dewatering well”.

The terms “test hole” and “dewatering well” do not include any well that is used or intended for use in the future as a source of water for agriculture or human consumption. A well that is used or intended for use in the future as a source of water for agriculture or human consumption must always comply with the *Wells Regulation* and the *Ontario Water Resources Act* requirements covered in this manual.

In some cases, ponds, reservoirs, lagoons, artificial wetlands, canals, trenches, tile drains, wick drains or ditches meet the definition of wells in the *Ontario Water Resources Act*. The *Wells Regulation* provides exemptions for these types of wells and this manual provides further descriptions of these wells.

Note: This manual is being provided for information purposes only and is not intended, nor should it be construed as providing legal advice in any circumstances. If there are any conflicts between this manual, and the *Regulation 903* of the Revised Regulations of Ontario, 1990 (Wells) made under the *Ontario Water Resources Act* (the *Wells Regulation*) or the *Ontario Water Resources Act*, the Act or the *Wells Regulation*, as the case may be, takes precedence over this manual. Anyone seeking legal advice about the matters discussed in this manual should consult a lawyer.

Note: This manual supercedes a number of previous Ministry publications including any and all fact sheets and technical bulletins regarding water wells in Ontario, published prior to January 2010, and the following:

- Water Wells and Groundwater Supplies in Ontario
- Tagging Ontario's Wells

How To Use This Manual

Each chapter in this manual is based on a specific topic of the well construction process. The Master Table of Contents found prior to Chapter 1 indicates the chapter titles.

Use this manual on the job and/or at the office to better understand, confirm and follow the requirements of the *Wells Regulation*, and go beyond the minimum requirements as recommended.

Note: Each chapter is intended to be read in conjunction with the entire manual and the chapters are not intended to be stand alone documents. Essential information may be missed if an individual chapter is taken out of the context of the manual.

Note: The graphics in this document

- are for illustrative purposes only,
- do not show all regulatory requirements, and
- are not to scale.

Note: The numbers and details presented in this manual are current as of the date of this publication. Any new regulation or legislation that has been written or revised following this date takes precedence over what is stated here.

Elements Included

Each chapter in this manual includes the following:

- Chapter Description – Describes the purpose of the chapter and gives an overall summary of the content covered within the chapter
- Regulatory Requirements – Summarizes the minimum requirements relevant to the chapter content
  - Relevant Sections – The *Wells Regulation* – Lists the sections of the regulation that are relevant and referenced within the chapter

    - The Requirements – Plainly Stated – Provides a "basic terms" summary of the requirements laid out in the *Wells Regulation*
    - Relevant Sections – Additional Regulations or Legislation – Lists additional sections of regulations or legislation that are relevant and referenced within the chapter
    - Relevant Standards – Lists additional standards that are relevant and referenced within the chapter
- Key Concepts – Provides an overview of the processes, procedures and the Best Management Practices for completing the task(s) relevant to the chapter. The Key Concepts are expanded upon in the chapters.
- Detailed Information – Expands upon the Key Concepts and provides best management practices
- Tools – Where appropriate, provides tools that may be helpful on the job when completing the task(s) relevant to the chapter

The manual also includes the following:

- Glossary – Provides a list of relevant terms and their definitions
- Ontario Legislation Section - Contains the following:
    - Ontario Water Resources – Provides the current version of the sections of the *Ontario Water Resources Act* relevant to wells
    - The *Wells Regulation* – Provides the current version of the *Wells Regulation*
- Resources – Provides quick access to important contact information and additional related resources

Role of Environmental Legislation and Regulations

Whenever an activity involves impacts to or potential impacts to the environment, a wide range of regulations are usually present at all levels of government.

- Impairment to any part of the natural environment has the potential to impact wildlife as well as human health and safety
- Environmental damage can exist in many forms including liquid waste in lakes, improper application of pesticides sprayed on food crops, excessive discharge of exhaust material into the atmosphere, entry of surface water or other foreign material into a well
- Environmental protection includes the protection of human health and public safety, as well as that of all living things
- It is a good business practice and good for everyone, to go beyond the minimum compliance requirements, that is – beyond the minimum standard

Lesgislation Relevant to Water Supply Wells: An Overview

Reference is made throughout this manual to the *Ontario Water Resource Act* (OWRA)

Well construction in Ontario is governed by the *Ontario Water Resources Act* and the *Wells Regulation*. The Ministry of the Environment and Climate Change's (the Ministry or MOECC) legislative authority to regulate water comes primarily from two acts, the *Ontario Water Resources Act* and the *Environmental Protection Act* (EPA).

The purpose of the *Ontario Water Resources Act* is to provide for the conservation, protection and management of Ontario's waters and for their efficient and sustainable use, in order to promote Ontario's long-term environmental, social and economic well-being. The *Ontario Water Resources Act*, which gives the Ministry extensive powers to regulate water supply, sewage disposal and to control sources of water pollution, expressly states in subsection 29(1) that for the purpose of the Act, the Minister has the supervision of all surface waters and groundwaters in Ontario.

The (EPA prohibits the discharge of contaminants to the natural environment, including water except where specifically permitted by an environmental compliance approval. The goals, policies, and guidelines set out in this document assist persons making decisions under or related to these Acts. They give, for example, directions that assist in defining site-specific effluent limits, which then may be incorporated into environmental compliance approvals or control orders. These control documents are issued under the authority of the legislation, and thus become legally binding and constitute the basis for compliance and enforcement actions. The policies and guidelines that are not incorporated into regulation or legislation by reference, do not have any formal legal status but, by their successful use over the years, are now seen as standard practices for water resources management.

There are other statutes that the Ministry uses to protect water resources and users, such as the *Safe Drinking Water Act, 2002* and the *Clean Water Act, 2006*. The *Clean Water Act* is not discussed in detail in this manual but the relevant sections of the *Safe Drinking Water Act* dealing with potable water are discussed in Chapter 14: Abandonment: When to Plug & Seal Wells.

There are many other important aspects of water management that do not fall under the jurisdiction of the MOECC, but are the responsibility of other provincial ministries and federal government departments, most notably the Ontario Ministries of Natural Resources, Health and Long Term Care, Agriculture Food and Rural Affairs, Conservation Authorities and the Federal Departments of Fisheries and Oceans and Environment Canada.

The *Ontario Water Resources Act* also sets out the consequences for non-compliance with the *Ontario Water Resources Act* and the *Wells Regulation*.

The *Wells Regulation*: An Overview

The *Wells Regulation* helps to ensure that groundwater quality, well water quality, and the environment are protected:

- The elements contained in the *Wells Regulation* are aimed at protection – of the resource, the well owner, the industry, and the well water
- The *Wells Regulation* identifies what must be done by the well contractor and the well technician to ensure that well construction activities do the following:
  - Protect aquifers and water resources,
  - Protect aquitards,
  - Protect water quality and quantity, and
  - Protect the health and safety of the well owner and users
  - Establish minimum standards for carrying out the elements of the work that have potential to have an impact on the well, the environment, human health and the owner

The *Wells Regulation* covers the following:

- Qualifications and requirements for obtaining and maintaining both well contractor and well technician licences
- Required steps before work on the well begins
- Required steps during the well construction process
- Approved materials and steps relating to casing, well screens, sealant, disinfection and pumping test
- Required steps for sealing the annular space
- Required steps to take after the well construction is complete such as notifications (e.g, tags and records)
- Requirements for when to abandon a well and how to seal a well
- Well owner's responsibilities
- Exemptions for certain types of excavations, activities, persons and shallow works

Protecting The Environment

A condition of both the well technician licence and the well contractor licence is that these licence holders must comply with all of the provisions of the legislation and *Wells Regulation* at all relevant times. Also, any other person working on a well must also comply with the legislation and the *Wells Regulation*. It is important to understand that carelessness or cost cutting during well construction and maintenance, costs everyone.

The nature of an aquifer makes it difficult, if not impossible to repair. Cleanup, if it is even possible, is very costly and positive results can take years to achieve. Remember that a single well can contaminate an entire aquifer, and affect the lives of many people.

The *Wells Regulation* and other legislation related to wells benefit all of the people of Ontario.

It is a privilege and a responsibility to be guardians or stewards of water, which is the basis of the livelihoods of licensed well technicians and other professionals. Each of us must do our part to protect groundwater from contamination, and all harmful practices.

Key Message

The *Wells Regulation* sets out the minimum requirements for well construction. It is a good idea to exceed these minimums where the professional judgment of the person constructing the well indicates that more is needed. During construction, situations may be identified where it may be beneficial to exceed the requirements to better protect the natural environment.

Penalties for Failing to Comply with *Wells Regulation* and Licensing Requirements

General penalties for an individual's non-compliance with a requirement of the *Ontario Water Resources Act* or the *Wells Regulation* include a maximum fine of $50,000 for each day or part of day on which the offence occurs or continues for the first conviction and $100,000 for each day or part of day on which the offence occurs or continues for each subsequent conviction and imprisonment for up to one year.

Corporate penalties for non-compliance with a requirement of the *Ontario Water Resources Act* or the *Wells Regulation* include a maximum fine of $250,000 for each day or part of day on which the offence occurs or continues for the first conviction and $500,000 for each day or part of day on which the offence occurs or continues for each subsequent conviction.

2. Definitions & Clarifications

Chapter Description

This chapter defines, clarifies and describes the terms used in the *Wells Regulation* and the *Ontario Water Resources Act* that are used in this manual. Other key terms used in this manual, which are not used in the *Wells Regulation* and the *Ontario Water Resources Act*, are described in the glossary.

Relevant Sections - The *Wells Regulation*

Definitions - Section 1

Relevant Sections - Additional Regulations Or Legislation

- *Ontario Water Resources Act*, R.S.O. 1990, Chapter 0.40 – Sections 1, 35(1), 35(2)
- *Environmental Protection Act*, S.O. 1999, Chapter 33
- *Safe Drinking Water Act*, S.O. 2002, Chapter 32
- *Regulation 169/03* as amended (Ontario Drinking Water Quality Standards) *Safe Drinking Water Act*, S.O. 2002, Chapter 32
- *Building Code Act*, S.O. 1992, Chapter 23
- *Regulation 350/06* as amended (Building Code) made under the *Building Code Act*, S.O. 1992, Chapter 23
- *Nutrient Management Act*, S.O. 2002, Chapter 4
- *Labour Relations Act*, S.O. 1995, Chapter 1
- *Agricultural Employees Protection Act*, S.O. 2002, Chapter 16

Key Definitions And Descriptions

Table 2-1: Terms and definitions found in the *Wells Regulation* Section 1, and the *Ontario Water Resources Act*

Term	Definition	Further clarification
Agency	The Ontario Clean Water Agency	Subsection 1(1) of *Ontario Water Resources Act*
Air Vent	An outlet at the upper end of the casing that allows for equalization of air pressure between the inside of the casing and the atmosphere and for the release of gases from the well	Subsection 1(1) of the *Wells Regulation*
Analyst	An analyst appointed under the *Environmental Protection Act*	Subsection 1(1) of *Ontario Water Resources Act*
Annular Space	An open space between a casing or well screen and the side of a well, and includes space between overlapping casings within the well	Subsection 1(1) of the *Wells Regulation* For the purposes of this manual the term “annulus” has the same meaning as annular space.
Aquifer	A water-bearing formation that is capable of transmitting water in sufficient quantities to serve as a source of water supply	Subsection 1(1) of the *Wells Regulation* See “Useful Aquifer” in Table 2-2 An “aquifer” is not dependent on the yield of water from a well. Instead, an “aquifer” is determined by its ability to transmit enough water into a particular well that yields a sufficient quantity for the user.
Assistant Well Technician	A person who works at the construction of wells as an employee or agent of the holder of a well contractor licence under the supervision of the holder of a well technician licence	Subsection 1(1) of the *Wells Regulation*

Term	Definition	Further clarification
Authorizing Certificate	Has the same meaning as in subsection 2 (1) of the *Ontario Labour Mobility Act, 2009*, S.O. 2009, c. 24	Subsection 1(1) of the *Wells Regulation* Subsection 2 (1) of the *Ontario Labour Mobility Act, 2009*, S.O. 2009, c. 24 states: "authorizing certificate", in relation to an occupation, means, a. a certificate, licence, registration, or other form of official recognition, granted by a regulatory authority to an individual, which attests to the individual being qualified to practise the occupation and authorizes the individual to practise the occupation, use a title or designation relating to the occupation, or both, or b. a certificate, licence, registration, or other form of official recognition, granted by a regulatory authority to an individual, which attests to the individual being qualified to practise the occupation but does not authorize the practice of the occupation or the use of a title or designation relating to the occupation, if the occupation and the regulatory authority granting the certificate, licence, registration or other form of official recognition respecting the occupation are prescribed for the purpose of this clause.
Bedrock	a. The solid rock underlying unconsolidated material such as gravel, sand, silt and clay, or b. solid rock that is exposed at the ground surface	Subsection 1(1) of the *Wells Regulation* This excludes glacial erratics or boulders as they are loose and unstratified and considered to be overburden. In Ontario, overburden is generally underlain by bedrock.
Bentonite	A commercially produced sealing material used in well construction or abandonment that, a. consists of more than 50% sodium montmorillonite by weight, b. has the ability to swell in the presence of water, c. does not provide nutrients for bacteria, and d. does not impair the quality of water with which it comes in contact	Subsection 1(1) of the *Wells Regulation*
Casing	Pipe, tubing or other material installed in a well to support its sides, but does not include a well screen	Subsection 1(1) of the *Wells Regulation*
Chlorinated	Disinfected with free chlorine residual	Subsection 1(1) of the *Wells Regulation*
Construct	When used with respect to a well, means bore, dig, drill or otherwise make, extend or alter. Construct also includes installing equipment in or connected to a well	Subsections 35(1) and 35(2) of the *Ontario Water Resources Act* An alteration includes the installation of a pump and associated pumping equipment in or connected to a well. Well abandonment is not considered to be well construction (see the description for "Well Abandonment" in Table 2-2).
Crown	Her Majesty the Queen in right of Ontario	Subsection 1(1) of the *Ontario Water Resources Act*

Term	Definition	Further clarification
Dewatering Well	A well that is not used or intended for use as a source of water for agriculture or human consumption and that is made: a. to lower or control the level of groundwater in the area of the well, or b. to remove materials that may be in the groundwater	Subsection 1(1) of the *Wells Regulation* Removal of materials could include a pump and treat well system that is removing contaminated groundwater from an aquifer.
Director	A Director appointed under section 5	Subsection 1(1) of the *Ontario Water Resources Act* Subsection 5(1) of the *Ontario Water Resources Act* for the purposes of the *Wells Regulation*
Discharge	When used as a verb, includes add, deposit, emit or leak and, when used as a noun, includes addition, deposit, emission or leak	Subsection 1(1) of the *Ontario Water Resources Act*
Flowing Well	A well that has a static water level above the ground surface	Subsection 1(1) of the *Wells Regulation*
Holder	When used in reference to a licence, permit or approval, means a person who is bound by the licence, permit or approval	Subsection 1(1) of the *Ontario Water Resources Act*
Inspection	Includes an audit, examination, survey, test and inquiry	Subsection 1(1) of the *Ontario Water Resources Act*
Justice	A provincial judge or a justice of the peace	Subsection 1(1) of the *Ontario Water Resources Act*
Land	Includes any estate, term, easement, right or interest in, to, over or affecting land	Subsection 1(1) of the *Ontario Water Resources Act*
Mineralized Water	Water containing in excess of 6,000 mg/L total dissolved solids or 500 mg/L chlorides or 500 mg/L sulphates	Subsection 1(1) of *Wells Regulation*
Minister	The Minister of the Environment	Subsection 1(1) of the *Ontario Water Resources Act*
Ministry, or MOECC	The Ministry of the Environment and Climate Change	Subsection 1(1) of the *Ontario Water Resources Act*
Minor Alteration	With respect to a well, a. routine repair or maintenance, b. the installation of monitoring, sampling or testing equipment, other than equipment used to test the yield of the well or the aquifer, c. the installation of a pump in a test hole, or d. the installation of a well cap or watertight well cover	Subsection 1(1) of the *Wells Regulation* See the description for “Routine Repair” in Table 2-2.

Term	Definition	Further clarification
Natural Environment	Has the same meaning as in the *Environmental Protection Act*	Subsection 1(1) of the *Ontario Water Resources Act* Subsection 1(1) of the *Environmental Protection Act* states: "natural environment" means the air, land and water, or any combination or part thereof, of the Province of Ontario. Section 2 of the *Environmental Protection Act* states: A contaminant that is discharged into the air within a building or structure as a result of the discharge of the same or another contaminant in another building or structure shall be deemed to be discharged into the natural environment by the owner or the person who has the charge, management or control of the contaminant discharged in the other building or structure.
Occupation	Has the same meaning as in subsection 2 (1) of the *Ontario Labour Mobility Act, 2009*, S.O. 2009, c. 24	Subsection 1(1) of *Wells Regulation* Subsection 2 (1) of the *Ontario Labour Mobility Act, 2009*, S.O. 2009, c. 24states: "occupation" means a set of jobs which, with some variation, are similar in their main tasks or duties or in the type of work performed
Out-of-province Regulatory Authority	Has the same meaning as in subsection 2 (1) of the *Ontario Labour Mobility Act, 2009*, S.O. 2009, c. 24	Section 1(1) of the *Wells Regulation* Subsection 2 (1) of the *Ontario Labour Mobility Act, 2009*, S.O. 2009, c. 24 states: "out-of-province regulatory authority" means a regulatory authority that is authorized to certify individuals in an occupation under an Act of Canada or of a province or territory of Canada that is a party to the Agreement on Internal Trade, other than Ontario.
Overburden	Unconsolidated material overlying bedrock	Subsection 1(1) of the *Wells Regulation*
Person Constructing a Well	A well technician or other individual who works at the construction of the well, and a well purchaser is not a person constructing a well.	Subsection 1(2) of the *Wells Regulation*
Province	The Province of Ontario	Subsection 1(1) of the *Ontario Water Resources Act*
Provincial Officer	A person who is designated under Section 5	Subsection 1(1) of the *Ontario Water Resources Act* Subsection 5(3) of the *Ontario Water Resources Act* for the purposes of the *Wells Regulation*

Term	Definition	Further clarification
Pump	Includes associated pumping equipment.	Subsection 1(1) of the *Wells Regulation* Equipment includes any equipment installed into or onto a well that is integral to the pumping of the well water Associated pumping equipment can include: • all the parts of a pump installed in a well • waterlines (sometimes called lateral pipes and drop pipes) and their associated parts in or attached to the well • pitless adapters and pitless units • sanitary well seals, and • electrical lines to operate a pump In some cases if a pump part is attached to the well cap or cover, the well cap or cover could also be associated pumping equipment.
Regulated Person	a. A person who belongs to a class of persons prescribed by the regulations and who holds or is required to hold, i. an approval, licence or permit under this Act, or ii. a certificate of approval, provisional certificate of approval, certificate of property use, licence or permit under the *Environmental Protection Act*, or b. a corporation that belongs to a class of corporations prescribed by the regulations	Subsection 1(1) of the *Ontario Water Resources Act*
Regulations	The regulations made under this act	Subsection 1(1) of the *Ontario Water Resources Act*

<table>
<tr><th>Term</th><th>Definition</th><th>Further clarification</th></tr>
<tr><td>Sealant</td><td>a. a slurry consisting of clean water and at least 20% bentonite solids by weight, or
b. other material that is equivalent to a slurry described in clause (a) with respect to the ability to form a permanent watertight barrier</td><td>Subsection 1(1) of the Wells Regulation

For the purposes of this manual the term “grout” has the same meaning as suitable sealant.

See also, definitions of “Clean” and “Watertight” in Table 2-2.

An approved material for sealant has to be a material that can provide as much of a permanent watertight barrier as the approved bentonite mixture in the environment the sealant will be used.

In problematic environments where bentonite is not sufficiently watertight, the definition of sealant could allow for other materials to be sands or gravels in a well’s annular space. However, the annular space must be sealed with a material that prevents any movement of water, natural gas, contaminants or other material between the subsurface formations, aquifers and/or ground surface and performs like (a) in a non-problematic environment.

In this case, other material could include but is not limited to the following:

• concrete or cement slurry,
• a layer or layers of concrete or cement with layers of clays, silts, sands, gravels, or other materials,
• a layer or layers of clays, silts, sands, gravels and drill cuttings, and/or
• a mechanical device such as a neoprene packer.

If the material is something other than a slurry consisting of clean water and at least 20% bentonite solids by weight, the material must form a watertight barrier that is equivalent to the bentonite/water slurry at the time the bentonite/slurry mixture is fully cured.</td></tr>
<tr><td>Static Water Level</td><td>The level attained by water at equilibrium in a well when no water is being taken from the well</td><td>Subsection 1(1) of the Wells Regulation

In equilibrium with the atmosphere.

Also requires that no water is being added to the well.</td></tr>
<tr><td>Subsurface Formation</td><td>Includes an aquifer</td><td>Subsection 1(1) of the Wells Regulation</td></tr>
<tr><td>Suitable Sealant</td><td>A sealant that is compatible with the quality of the water found in the well</td><td>Subsection 1(1) of the Wells Regulation

For the purposes of this manual the term “grout” has the same meaning as suitable sealant.

See also definition of “Sealant” and “Bentonite” in this table.</td></tr>
<tr><td>Test Hole</td><td>A well that,

a. is made to test or to obtain information in respect of groundwater or an aquifer, and
b. is not used or intended for use as a source of water for agriculture or human consumption</td><td>Subsection 1(1) of the Wells Regulation

For further clarification see the term “well” below in Table 2-1.</td></tr>
</table>

Term	Definition	Further clarification
Tremie Pipe	A pipe or tube with an inner diameter that is at least three times the diameter of the largest particle of material to pass through it and that is used to conduct material to the bottom of a hole, including a hole containing standing water	Subsection 1(1) of the *Wells Regulation* When used, a tremie pipe includes a float shoe or other similar devices if they are used to conduct material to the bottom of a hole. For clarification with respect to a tremie pipe, a pipe or tube means a long, hollow (empty space) cylinder.
Tribunal	Means the Environmental Review Tribunal	Subsection 1(1) of the *Ontario Water Resources Act*
Waters	A well, lake, river, pond, spring, stream, reservoir, artificial watercourse, intermittent watercourse, groundwater or other water or watercourse	Subsection 1(1) of the *Ontario Water Resources Act*

Term	Definition	Further clarification
Well	A hole made in the ground to locate or to obtain groundwater or to test or to obtain information in respect of groundwater or an aquifer, and includes a spring around or in which works are made or equipment is installed for collection or transmission of water and that is or is likely to be used as a source of water for human consumption.	Subsection 1(1) of the *Ontario Water Resources Act* There are three parts to the definition: 1. a hole used to locate or obtain groundwater is a well 2. a hole to test or obtain information with respect to groundwater or an aquifer is a well 3. a spring (natural groundwater discharge at ground surface) where works or equipment are installed and where the water will, or is likely to be used for human consumption is a well. The *Wells Regulation* exempts certain types of wells. The exempt wells are: trench, pond, ditch, reservoir, lagoon, artificial wetland, canal, tile drain and wick drain. See descriptions of these terms in Table 2-2. If a hole is advanced or excavated to test or obtain information with respect to an aquifer or groundwater but the hole does not locate groundwater (i.e., a dry hole), the hole is still considered a well. If a hole is made for the sole purpose of overburden and bedrock observations, with no direct or indirect observations regarding the presence or absence of any groundwater, the hole is not a well. If a hole is made below a surface water body for the sole purpose of sediment, overburden and bedrock observations, the hole is not a well. When dealing with earth energy (geothermal) systems it is important to consider the following: • In a geothermal system identified as an open loop system (or aquifer thermal energy storage system), groundwater is usually taken from a hole into a heat exchanger or heat pump. This hole meets the definition of a "well." • If water is discharged back from the heat exchanger or pump to the aquifer through another hole, then the hole is also considered a "well." Sometimes the same hole is used to take groundwater and discharge the water back into the aquifer in an open loop system. This hole meets the definition of a "well." • If the hole is advanced or excavated to locate or obtain groundwater but the hole does not locate groundwater (i.e., a dry hole), the hole is still considered a "well." • If the earth energy (geothermal) system is considered a closed loop system and a person conducts a test (including a short duration pumping test or hydraulic conductivity test) on the groundwater in the hole, then the hole is a "well." In some cases a test may include a small pumping test to determine if the rate of groundwater flow during drilling or development will exceed 50,000 litres per day, and to ensure compliance with the Permit To Take Water requirements found in Section 34 of the *Ontario Water Resources Act*. • Some earth energy (geothermal) closed loop systems use groundwater to transfer (i.e., conduct) energy to and from the heat transfer fluid. If the person is looking for, or obtaining information about, groundwater in the holes, for these systems, then the holes are considered "wells." • For further information on earth energy (geothermal) systems please see the technical bulletin titled Constructing Earth Energy Systems in Ontario on the Ontario website.

Term	Definition	Further clarification
Well Contractor Licence	A licence referred to in section 39	Subsection 35(1) of the *Ontario Water Resources Act* A licence issued by the Director that authorizes the holder to engage in the business of constructing wells. See Chapter 3: Well Construction Licences: Obtaining, Maintaining & Exemptions.
Well Technician Licence	A licence referred to in section 43	Subsection 35(1) of the *Ontario Water Resources Act* A well technician licence is a licence of a prescribed class issued by the Director that authorizes the holder to work at the construction of wells. There are five different classes of well technician licences each authorizing different well construction activities. See Chapter 3: Well Construction Licences: Obtaining, Maintaining & Exemption.
Well Owner	The owner of land upon which a well is situated and includes a tenant or lessee of the land and a well purchaser	Subsection 1(1) of the *Wells Regulation* This means all three types of person; owner of land, tenant/lessee and well purchaser. In some cases multiple parties are responsible for maintaining or abandoning a well. Can mean an individual or individuals including corporations. Obligations from the person constructing the well to the well owner are to: • notify of mineralized water and natural gas occurrences, • provide with well record, and • provide with well record, and • provide written consent where required (e.g., during disinfection). Obligations of the well owner are to: • maintain the well as required, • abandon the well where required, and • provide written consent where required (e.g., during disinfection).

Term	Definition	Further clarification
Well Purchaser	A person who enters into a contract for the construction of a well with a person who is engaged in the business of constructing wells	Subsection 1(1) of the *Wells Regulation* A well purchaser is not a person constructing a well. Can mean an individual or individuals including corporations. Obligations from the person constructing the well to the well purchaser are to: • notify of mineralized water and natural gas occurrences, • provide with well record, • provide with an information package, • provide with a water sample where required, and • measure the depth of the well where required Obligations of the well purchaser are to: • maintain well as required, • abandon well where required, and • provide written consent where required (e.g., during disinfection)
Well Record	A form supplied by the Ministry for recording information about a well during construction or abandonment of the well	Subsection 1(1) of the *Wells Regulation*
Well Screen	Perforated pipe or tubing, unsealed concrete tiles or other material installed in a well to filter out particulate matter and form the water intake zone	Typically, well screens for drilled wells are manufactured with specific slot sizes to prevent the formation's materials from entering the well. Persons constructing wells can slot or perforate casings to create well screens or install concrete casings with unsealed joints to create well screens. For new well construction, where the person uses concrete tiles as well casing and well screen, the well screen begins at the first unsealed joint in the concrete tiles and ends either at the bottom of the unsealed concrete tiles or any gravel or sand installed below the tiles in the excavated hole.

Term	Definition	Further clarification
Well's Structural Stage Completion	A well's structural stage is complete on the day on which the well is capable of being used for the purpose for which it was constructed but for: a. compliance with Section 15; b. the installation of a pump, or c. any alterations necessary to accommodate pumping, monitoring, sampling, testing or water treatment equipment	Subsection 1(3) of the *Wells Regulation* By the time the well is ready to be used, except for the installation of the pump and disinfection, the person constructing the well must, unless exempt, have met certain obligations, such as the: • well has been developed, • well yield has been tested, and • well tag has been affixed to the well in accordance with the *Wells Regulation*. On completion of the well's structural stage, the person constructing the well must, unless exempt, meet the well record completion requirements. If a well is being altered (other than a minor alteration or pump installation), such as installing a liner or casing sleeve in a well, the person has structurally disabled the well from being used for the purpose for which it was constructed. After the alteration has been completed on the well, the well is again capable of being used for the purpose for which it was constructed. A person must then disinfect the well (see Chapter 8: Well Disinfection) and complete a well record (see Chapter 13: Well Records, Documentation, Reporting & Tagging). This term does not apply to well abandonment because the well is not capable of being used after it has been properly plugged and sealed.

The terms described in Table 2-2 are for the purposes of providing clarification with respect to the *Wells Regulation* and may have other meanings in different contexts or in relation to other legislation. Unless otherwise indicated, they are derived from the ordinary dictionary meaning of the word.

Additional terms can be found in the Glossary at the end of this manual.

Table 2-2: Other Terms In Addition To Those Defined In The *Wells Regulation*

Term	Description	Further clarification

<table>
<tr><th>Term</th><th>Description</th><th>Further clarification</th></tr>
<tr><td>Agriculture</td><td>For clarification purposes, “agriculture” is defined in the Labour Relations Act and the Agricultural Employees Protection Act.

“Agriculture” includes farming in all its branches, including dairying, beekeeping, aquaculture, silviculture and horticulture.

Agriculture includes the raising of livestock including non-traditional livestock, furbearing animals and poultry, the production, cultivation, growing and harvesting of agricultural commodities, including eggs, maple products, mushrooms and tobacco, and includes any practices performed as an integral part of an agricultural operation.</td><td>The Nutrient Management Act also provides a definition for the term “agricultural operation.” An “agricultural operation” includes:

• Draining, irrigating or cultivating of land
• Growing, producing or raising farm animals
• The production of agricultural crops including greenhouse crops, maple syrup, mushrooms, nursery stock, tobacco, trees and turf grass
• The production of eggs, cream and milk
• The operation of agricultural machinery and equipment
• Ground and aerial spraying
• The management of materials containing nutrients for farm purposes
• The processing by a farmer of the products produced primarily from the farmer’s agricultural operation
• Activities that are a necessary but ancillary part of an agricultural operation such as the use of transport vehicles for the purposes of the agricultural operation
• Any other agricultural activity prescribed by the regulations under the Nutrient Management Act, conducted on, in or over agricultural land</td></tr>
<tr><td>Artificial Wetlands</td><td>Wetlands that are artificially created.

Includes human-made permanently or intermittently wet areas, shallow water, and land water margins that support an ecosystem of plants and animals that are adapted to wet conditions.</td><td>Artificial wetlands are exempt from Sections 36 to 50 of the Ontario Water Resources Act and the Wells Regulation.</td></tr>
<tr><td>Breakaway Guide</td><td>A device that aids in proper alignment of the casing when using a cable tool rig by centering the casing. It must not impair the quality of the water with which it comes into contact and must be placed 2 m (6.5ft) above the bottom of the casing.</td><td>The breakaway guide is placed 2 m (6.5ft) from the bottom of the leading casing during installation.</td></tr>
<tr><td>Canal</td><td>An artificial channel for surface water that may intersect groundwater. There are two types of canals: irrigation canals, which are used for the delivery of water, and waterways, which are navigable transportation canals.</td><td>Canals are exempt from Sections 36 to 50 of the Ontario Water Resources Act and the Wells Regulation.</td></tr>
</table>

Term	Description	Further clarification
Clean	The word "clean" is used in different contexts in the regulation. With respect to equipment, clean means all visible dirt, debris and material have been removed. With respect to water, clean means water that will not interfere with the reaction to make a bentonite, concrete or cement slurry as recommended by the manufacturer and will not impair the well water. With respect to sand or gravel material, clean means that it should at least: • be washed with clean water to remove finer textured material, and • not cause an impairment of the well water	When installing any type of equipment in a well, it is a best management practice that the equipment is not only clean but also disinfected. When installing clean sand or gravel, it is a best management practice to meet the parameter concentrations of Table 1 in Soil, Groundwater and Sediment Standards for Use under Part XV.1 of the *Environmental Protection Act*, April 15, 2011 [1] . A copy is available on the Ontario website.
Clear	As it refers to well water, "clear" means that all debris, including well cuttings and drilling fluids, have been removed from the well and well water; and the water is transparent or unclouded. This does not mean without any naturally occurring colour associated with the well water.	For example, groundwater can turn an orange colour where naturally occurring iron is present in the groundwater and formation. Groundwater can turn a black colour where naturally occurring iron sulphide is associated with the groundwater. Both of these samples could be "clear" for the purpose of the well development requirements in the *Wells Regulation*.
Commercially Manufactured Vermin-proof Well Cap	A cap that creates a vermin-proof seal at the top of the well. A typical cap consists of top and bottom pieces with a rubber gasket in between. The bottom piece is connected to the well casing. The top piece is fastened to the bottom piece. The cap contains a port to house an electrical conduit or plug, as applicable. Also, the cap contains screened and shielded air vents.	Can also mean a sanitary well seal. See Chapter 9: Equipment Installation, "Well Caps and covers," for more information.

Term	Description	Further clarification
Contaminant	As guidance and for the consideration of the person installing a well, “contaminant” means any solid, liquid, gas, odour, heat, sound, vibration, radiation or any combination of the above resulting directly or indirectly from human activities that causes or may cause an adverse effect. (As per *Environmental Protection Act*, R.S.O. 1990. c. E 19 (EPA), ss.1. “Source of contaminant” means anything that discharges into the natural environment any contaminant (As per the *Environmental Protection Act*, R.S.O., 1990. c. E 19 (EPA) ss 1(1)).	Source of contaminants means the actual source of the contamination and not the pathway that a plume of contaminants would take from the source through the overburden and/or bedrock. Assessing and determining potential sources of contaminants that fit the definition of source of contaminants is dealt with on a case by case basis. A source of contaminants list may include but is not limited to the following: • All components of a sewage system under the *Building Code Act*, the *Ontario Water Resources Act* or the *Environmental Protection Act* • A farm animal feed lot • An animal manure pile • A barn and barnyard • A lagoon • An underground or above ground storage tank and lines that are designed to hold and move petroleum hydrocarbons, volatile organic compounds, polychlorinated biphenyls, phenols and other organic chemicals • An open or closed hazardous or non hazardous landfill or dump • A sewer line • A pond • Fertilizers, pesticides, herbicides and other chemical storage areas • Liquid or solid waste transfer facilities • Sewage sludge and biosolid waste spreading and irrigation sites • Winter sand and salt storage facilities

Term	Description	Further clarification
Contaminated Area or Site	Means an area that contains a contaminant. See definition of "contaminant".	Also see "Contaminant" in Table 2-2. To help determine if the site has an area that is considered a contaminated area, a person constructing a shallow works should: • review previous hydrogeological and geological reports for the site, • assess the formations, and • use the Guideline titled Soil, Ground Water and Sediment Standards for Use under Part XV.1 of the *Environmental Protection Act* [2] . For further information on shallow works, see Chapter 3: Exemptions: Wells, Activities & Experienced Professionals. In determining whether a roadway is a contaminated area, a person constructing a well should consider *Regulation 339* as amended made under the *Environmental Protection Act*. Section 2 of *Regulation 339* provides: • Where any substance in or on the ground that was used on a highway by the Crown as represented by the Minister of Transportation or any road authority or any agent or employee of any of them for the purpose of keeping the highway safe for traffic under conditions of snow or ice or both is a contaminant, it is classified and is exempt from the *Environmental Protection Act* and the regulation. Substances exempted by *Regulation 339* and used as specified in that regulation do not create a contaminated area for the purposes of the shallow works exemption. Salt storage domes or spills of salt are not captured by the above exemption.
Ditch	An excavation that is created to channel water. A ditch can also be used for drainage of low lying areas, alongside roadways or fields.	A ditch is exempt from Sections 36 to 50 of the *Ontario Water Resources Act* and the *Wells Regulation*.
Double Walled Casing	As guidance to a person constructing a new well, a double walled casing in the *Wells Regulation* includes an inner casing within an outer permanent casing. The outer casing must surround the inner casing for part or all of the inner casing's length.	The inner casing, or casings, can extend above the top of outer casing or can extend below the bottom of the outer casing. The annular space between the casings in a new well must be sealed with suitable sealant to prevent the entry of surface water and other foreign materials.

Term	Description	Further clarification
Driven Point/Use of a Driven Point	A solid point or cone that is driven into the ground.	Driven point construction method means a method that uses a solid point or cone that is driven into the ground. This does not include a cutting shoe unless a solid point is installed on an inner rod. This method is not machinery specific. For example, the type of machinery that can be used to drive the solid point or cone into the ground can include direct push technology, rotary, percussion, pneumatic hammers, sonic, non-powered manual ethods, and cone penetration testing equipment.
Equipment Used to Test the Yield of the Well or the Aquifer	Equipment used to test the yield of the well includes a pump that is used to conduct a pumping test.	The equipment referred to in the column to the left includes equipment used to measure the water levels in the well during and immediately after a yield or pumping test. Examples of water level measuring equipment include: • A pressure transducer and datalogger system, • An electrical water level device, • An air line to measure water levels. Flow meters used to measure the rate of water during the test are also considered equipment used to test the yield of the well. This term does not include water level measurement devices, sampling devices or pumps that are installed for purposes other than testing the yield of the well. Certain sections of the *Wells Regulation* dealing with licensing and exemptions refer to this term. See the description of “Well Yield” in Table 2-2.
Free Chlorine Residual	The amount of chlorine available as dissolved gas (Cl_2), hypochlorous acid (HOCl), and hypochlorite ion (OCl^-), that is not combined with ammonia (NH_3) or other compounds in water.	The Procedure for Disinfection of Drinking Water in Ontario (As adopted by reference by *Ontario Regulation 170/03* made under the *Safe Drinking Water Act*) [3] by the Ministry of the Environment and Climate Change provides helpful definitions for free (available) chlorine residual, total chlorine residual and combined (available) residual chlorine in footnotes 4, 5 and 6 on page 6. An online resource is available on the Ontario website.
Free of Sand (Essentially Sand Free)	Sand free water or essentially sand free water is water from a new well that has been developed and is producing water that is free and clear of any fine grain materials, such as clay, silt, or sand.	
High Yield Well	A well that can yield a rate of more than 60 litres per second could be considered a high yield well.	
Lagoon	May include an engineered excavation designed to hold waste or wastewater or in some cases allow for the exfiltration of the waste.	Lagoons are exempt from Sections 36 to 50 of the *Ontario Water Resources Act* and the *Wells Regulation*; however, they are subject to approval instruments under the *Ontario Water Resources Act* or the *Environmental Protection Act*.

Term	Description	Further clarification
Licensee	Holder of a well contractor licence or a well technician licence, as the case requires.	
Log of Overburden and Bedrock Materials	A log of overburden and bedrock materials or geologic log is required to be recorded on a well record. The Ministry provides instructions on how to make general observations and complete the log of overburden and bedrock materials intersected by the hole or excavation.	
Mastic Material	Mastic material is a preformed, manufactured material used to seal the joints between two concrete casing sections that: • Remains pliable and waterproof, • Is approved for potable water use by the NSF International Standard 61. (Search NSF Certified Drinking Water System Components)	It is commonly made of a bitumen or butyl rubber sealant product. As a best management practice, it should at the least meet the ASTM C990M-06 [4] standard titled: Standard Specification for Joints for Concrete Pipe, Manholes, and Precast Box Sections Using Preformed Flexible Joint Sealants.
Mineral Exploration	For clarification purposes, "mineral exploration" is defined in *Ontario Regulation 504/95: Exemption – Prospectors* made under the *Environmental Protection Act*, R.S.O. 1990, c. E.19 "Mineral exploration" means prospecting, staking or exploration for minerals and any activities related to prospecting, staking or exploration for minerals, and includes advanced exploration as defined in Part VII of the *Mining Act*.	"Minerals" means all naturally occurring metallic and non-metallic minerals, including coal, salt, quarry and pit material, gold, silver and all rare and precious minerals and metals, but does not include sand, gravel, peat, gas or oil.
Natural Gas	Natural gas or other gas is a gas produced from a well that has the potential to create conditions for explosions, poisoning, fire, asphyxiation or other adverse effects at the well site, within the water distribution system connected to the well or within buildings connected to wells. Some problematic gases that have been found in wells in Ontario include methane, hydrogen sulphide, propane, butane, benzene, carbon dioxide and other hydrocarbon based gases.	If any natural gas is observed by smell, feel or vision or detected by a meter at any concentration, the gas must be immediately reported to the Director (Spills Action Centre at), well purchaser and well owner. If the release or discharge of the natural gas or other gas causes, or may cause, an adverse effect to the natural environment, section 15 of the *Environmental Protection Act* requires the person constructing the well to report the release to the Spills Action Centre ().
New Well	A well is considered to be a "new well" at the time when the initial hole (test hole or dewatering well) is constructed.	The obligation to meet new well requirements in the *Wells Regulation* is placed on the person constructing a well and applies during the construction of a new well and its parts (e.g., casing, annular space etc.).
Non Powered Equipment	Non-powered equipment includes well construction or abandonment equipment which is used without the need for a power source such as electricity, petroleum fuel or pressurized water.	
Original ground surface	The surface of the ground at the well site immediately prior to well construction or well abandonment.	
Overdrilling	Re-drilling an existing well using a drill bit that is larger than the diameter of the existing well casing or hole. The drilling operation reams (or rips) out the existing well's casing and annular seal.	The technique is typically used to remove and install new well casing in a well rehabilitation operation or used to plug and seal a well.
Permanent	The word permanent means a one time installation that is intended to last indefinitely.	

Term	Description	Further clarification
Person Abandoning the Well	In the case of a well that must be immediately abandoned, the person abandoning the well is one of the following: - the person who has discontinued the construction of a new well prior to the completion of its structural stage - the well purchaser of a new well that is dry - the well owner of a well that: - is not in use or being maintained for future use as a well, - is producing water that is mineralized or not potable (not applicable to test holes or dewatering wells), - is producing water that is mineralized or not potable (not applicable to test holes or dewatering wells), - permits the movement of materials including natural gas and contaminants and the movement may impair the quality of the waters, or - is constructed in contravention of the *Wells Regulation* requirements for location, methods, materials or standards and measures taken to rectify the problem have failed.	
Pond	A natural or human-made depression, smaller than a lake that collects groundwater and/or surface water.	
Potable Water	Water that meets, at a minimum, the Drinking-Water Quality Standards found in *Ontario Regulation 169/03* as amended under the *Safe Drinking Water Act*.	
Previously Installed	Equipment found to be already installed into the well when arriving at the well is considered to be equipment that has been previously installed.	Some monitoring equipment is allowed to be left unattended in wells because the equipment has been previously installed in the wells. For example, a pump and pumping equipment have been installed into a well by a licensed well technician. The person can use the previously installed pump and pumping equipment to sample water from the well and be exempt from the licensing requirements in respect of sampling and monitoring in the *Ontario Water Resources Act* and the *Wells Regulation*.
Property	A property is a piece of real estate owned by an individual or a corporation. An example of a property would be a piece of land owned or deeded to a person. Another example of property would be an entire roadway owned by a road authority.	
Recommended Pumping Rate	The estimated sustainable yield of the well based on the well yield test.	The recommended pumping rate will reflect the efficiency of the well screen (if present), the development of the well and the nature of the formation (aquifer) and should allow for a sufficient safety margin. The recommended pumping rate should be calculated to prevent water shortages and formation collapse around a well screen. The person conducting the well yield test must report the recommended pumping rate on the well record.
Reservoir	An artificial lake used for the storage and control of water.	Reservoirs are exempt from Sections 36 to 50 of the *Ontario Water Resources Act* and the *Wells Regulation*.

Term	Description	Further clarification
Routine Repair	A routine repair or routine maintenance on a well occurs when a person is following a sequence of actions regularly undertaken with respect to a well or is performing a regular procedure on a well	An example of routine maintenance may be removing the well cap and verifying the condition of the casing and pump waterline annually. The following are examples of activities that are **not** considered to be routine repairs or maintenance: • Adding a well casing extension • Cutting casing • Deepening a well • Replacing a casing • Installing a well screen in a well • Pulling a pump and/or a waterline from a water supply well and re-installing the equipment in the well. • Changing a pitless adapter attached to well casing • Measuring water levels in a well with a water level meter while performing a constant rate, step pumping test in the same or another well. • Using equipment in the redevelopment or rehabilitation of an existing well, such as during hydraulic fracturing. See the definition of “Minor Alteration” in Table 2-1.
Slot Number	Manufacturer’s designate slot openings on a manufactured well screen by a number. The number matches the width in the slot openings in thousandths of an inch. For example a number 10 slot is an opening of 0.010 inches (which is converted to 0.25 mm). For smaller diameter well screens covered by wire mesh, manufacturers designate mesh number openings by a gauge number instead of a slot number. For example a number 10 slot equals a gauge number 60 [5] .	
Slurry	A mixture of liquid, especially water, and any of several divided substances, such as cement or clay particles.	
Tile Drain	A pipe surrounded by granular material to collect and convey water.	Tile drains are exempt from Sections 36 to 50 of the *Ontario Water Resources Act* and the *Wells Regulation*.
Trench	An elongated excavation where the excavation depth typically exceeds the excavation width.	Trench drains are exempt from Sections 36 to 50 of the *Ontario Water Resources Act* and the *Wells Regulation*.
Unattended	Refers to the circumstance when a person working on a well is no longer in control of or watching the specific well.	Examples of leaving the well unattended can include leaving the property, working on another well while not being present at the original well or not being in control of the well site.

Term	Description	Further clarification
Useful Aquifer	An aquifer is defined as a water-bearing formation that is capable of transmitting water in sufficient quantities to serve as a source of a water supply. For the purposes of the *Wells Regulation* the terms “useful” and “aquifer” are considered qualitative terms that are applied on a case by case basis. The term “useful” in relation to aquifer could mean: • A formation that yields sufficient supplies of water; • The water quality has to be suitable for the person’s purposes; • A material associated with the formation, such as a natural gas, has to be suitable for the person’s use; • The depth of the aquifer is such that it is economically feasible to drill, install devices and/or install pumping equipment to obtain the aquifer’s groundwater; or • The quality of the water in the aquifer is such that it is economically feasible to install treatment devices to obtain suitable water.	The *Wells Regulation* requires that a new well be at least 6 m (20ft) deep, unless the only useful aquifer available necessitates a shallower well, in which case the well must be at least 3 m (10ft) deep.
Water Intake Zone	The location of a well screen and installed sand or gravel material beside and below the well screen is considered the water intake zone of a well. Some wells are constructed with casing into overburden deposits. The bottom of the casing is completely open. Sometimes coarse material such as gravel or sand is placed below the open casing which is typical of large diameter dug and bored wells. In this type of well construction, any installed sand and gravel below the well and the open bottom area of the well casing is considered to be the water intake zone. In other situations wells are constructed with casing into bedrock deposits. In many cases, the hole below the casing is open in the bedrock (this portion is typically referred to as “open hole”). In these environments, the bedrock will typically be sufficiently strong prevent the formation from collapsing into the open hole. The open hole is designed to intersect one or more groundwater bearing bedrock fractures that will supply groundwater to the well. Thus, the entire open portion of the well below the well casing is considered a water intake zone.	

Term	Description	Further clarification
Water Producing Zone	The meaning of "water producing zone" is understood differently depending on the well construction and formation. The following can be considered a water producing zone: • A well screen • A water intake zone at the bottom of an open well casing completed into an overburden formation • A bored well using concrete tiles with unsealed joints may encounter groundwater in two separate formations separated by a confining formation. Both groundwater producing formations are considered two separate water producing zones in the well. • A groundwater bearing fracture intersected by a well where a well is constructed as an open hole in the bedrock.	
Waterproof	"Waterproof" and "watertight" have the same general meaning.	
Watertight	Watertight means closely sealed, fastened or fitted so as to prevent the passage of water. A person should not be able to observe water movement through a joint, seam, seal or material using an appropriate performance test for the material. In the case of a watertight connection, well cover or flush mounted cover, "watertight" means a person cannot visually observe water or other foreign materials leaking or moving through any portion including the joint of the cover or connection.	See "Sealant" in Table 2-1 for further clarification on watertight materials. Most pipe is taper threaded with a rubber gasket to provide water tight joints.
Weathered Bedrock	Weathered unconsolidated rock in the basal subsoil or highly fractured rock commonly found above the competent (solid) bedrock. Based on its characteristics and the behaviour of groundwater in weathered bedrock, unconsolidated rock in the basal subsoil is generally considered as part of the overburden rather than as bedrock.	Basal subsoil is considered the deepest layer of overburden immediately above the bedrock.
Well Abandonment	The circumstances and timeframes in which a well must be abandoned and the requirements to be complied with when abandoning a well. Well abandonment and the activities associated with well abandonment are not considered to be "constructing a well" or "well construction activities."	
Well Development	A method, such as surging or blowing, used to do the following: • remove any water or drilling fluid introduced during well construction, • stabilize the filter pack and formation material around the well screen, • minimize the amount of fine grained material entering the well; and • improve the well efficiency and inflow of water into the well.	

Term	Description	Further clarification
Well Opening	The open area within the well casing or an excavation from the ground surface to at least 2 metres below the ground surface at the site of an abandoned well. If an excavator is used to remove well casing during a well abandonment (plugging and sealing), the well opening can be larger than the diameter of the well.	During the plugging and sealing of a well, the entire well opening must be filled with bentonite chips, pellets, granules or powder to a thickness of 0.5 to 1.5 metres thick in the well opening. The remainder of the well opening must be filled with soil cover or other material more in keeping with the surface material immediately adjacent to the well opening, to prevent inadvertent or unauthorized access. Requirements for filling a "well opening" are found in Chapter 15: Abandonment - How to Plug and Seal Wells.
Well Pit	An enclosed structure located at and below the ground surface that houses the top of the well and any associated pumping equipment. The well pit: • Protects the well from outside environmental conditions such as the prevention of waterline freezing, surface water runoff and other foreign materials, and • Allows access to the well from the land surface for well and pumping system maintenance.	
Well Production Rate	The well production rate is the estimated maximum sustainable yield of the well water based on the well yield test.	The person conducting the well yield test must report the well production rate on the well record.
Well Tag	An identification tag with a unique alphanumeric identifier obtained from the Ministry to be affixed to the outside of or near the well casing.	The tag links the well in the field with the well record. For further information, see Chapter 13: Well Records, Documentation, Reporting & Tagging.
Well Yield	The well yield is the volume of water discharging from a well over a period of time.	Well yield testing, or testing the yield of the well requirements are found in sections 14.9 and 14.10 of the *Wells Regulation*.
Wick Drain	A piece of equipment such as a prefabricated plastic core wrapped in a geotextile cloth, which is pushed into the ground and draws water from the soil to accelerate the settlement of soils.	Wick drains are used in the construction of highways and roads, bridge abutments, railways, dykes and dams, and other structures that are built on soft, saturated, compressible soils. Wick drains are exempt from Sections 36 to 50 of the *Ontario Water Resources Act* and the *Wells Regulation*.

3. Well Contractors & Well Technician Licenses, Responsibilities & Exemptions

Chapter Description

This chapter provides an explanation of the requirements related to licensing for well construction activities. Licensing is a process that sets minimum requirements for experience, knowledge, and familiarity with well construction in Ontario. Well contractor licences are required by a person or partnership or company that engages in the business of well construction. Well technician licences of different classes are required for individuals who work on the construction of wells, unless they are exempt. There are supervision requirements for assistant well technicians who work with well technicians. For activities that are considered to pose a lower environmental risk,

exemptions to licensing have been created. There are also requirements for the person abandoning the well (often the well owner) to hire a holder of a well contractor licence unless s/he is exempt.

Regulatory Requirements - Licences

Relevant Sections - The *Wells Regulation*

- Exemptions – Section 1.0.1 to 1.0.3
- Well Contractor Licence – Sections 2 to 4
- Well Technician Licence – Sections 5 to 7
- Examination – Section 8
- Continuing Education – Well Technicians – Section 8.1
- Assistant Well Technician – Sections 9 to 10
- Abandonment – Subsection 21(13)

The Requirements & Exemptions - Plainly Stated

Well Contractor Licence

A person, partnership or company engaging in the business of well construction is required to obtain and maintain a well contractor licence unless exempt under the *Wells Regulation*.

Well Technician Licence

A person working at well construction is required to obtain and maintain a well technician licence of a prescribed class unless exempt under the *Wells Regulation* or the *Ontario Water Resources Act*. The prescribed classes are shown in “Well Technicians – Licence Classes,” on this chapter.

Reminder: Details on requirements to obtain and maintain licences, including continuing education, are discussed in the section titled “Continuing Education for a Well Technician Licence Holder” on this chapter.

Exemption - Well Technician Licence

An individual land owner or his/her family members can work on any well situated on his/her own property without a well technician licence. Also, other individuals can construct a well without a well technician licence for the individual land owner as long as no form of compensation is made.

Reminder: If the land owner is a business (corporation, partnership, sole proprietor) or a provincial government agency, an employee must have a proper well technician licence to construct a well and the business or government agency must have a well contractor licence.

Assistant Well Technician(Helper/Labourer)

Definition - A person who works at the construction of wells as an employee or agent of the holder of a well contractor licence under the supervision of the holder of a well technician licence.

An assistant well technician may, or may not, hold a Ministry-issued identification card.

An Assistant Well Technician Who Holds an Identification Card

A person who holds an assistant well technician identification card is exempt from requiring a well technician licence when working at the construction of wells on behalf of the licensed well contractor named on the card if:

- the expiry date on the card has not yet been reached,
- s/he carries the card and produces it on the request of an employee or agent of the Ministry, and
- s/he is supervised by the holder of a well technician licence, of the correct class of licence for the well construction activity, who is available to be called to the site within one hour.

An Assistant Well Technician Who Does Not Hold an Identification Card

An assistant well technician without an identification card, issued under the *Wells Regulation*, is exempt from requiring a well technician licence if the assistant well technician is supervised by a holder of a well technician licence, of the correct class of licence for the well construction activity, who is present at the site at all times.

Reminder: An exempted professional [e.g., Professional Engineer (P. Eng), Professional Geoscientist (P. Geo), and Certified Engineering Technologist (CET)] who does not hold a well technician licence, but who works for a holder of a well contractor licence can only supervise a person who is conducting well construction activities associated with a Class 5 well technician licence if the supervised person:

- is an exempted professional or
- holds a valid Class 5 well technician licence.

If the exempted professional intends to supervise an "assistant well technician", the exempted professional must hold the correct class of well technician licence.

Exemptions – Construction Activities, Including Licensing

Sections 36 to 50 of the *Ontario Water Resources Act*, including licensing requirements, and the *Wells Regulation* do not apply to any of the following activities that are part of the construction of a well:

- Inspecting the well using equipment that is not left unattended in the well.

  Examples of such equipment include: video or a down the hole camera.

  Inspecting a well includes removing thr well equipment or parts of a well such as a cap or cover to perform the inspection.

- Monitoring, sampling or testing the well using equipment that,

  - is not used to test the yield of the well or the aquifer, and is not left unattended in the well, or
  - is not used to test the yield of the well or the aquifer, and was previously installed in the well.

  Examples of such equipment include: a water level indicator to measure water levels, a small submersible pump or inertial pump to sample groundwater and conductivity, dissolved oxygen and pH meters to test groundwater.

- Installing equipment for monitoring, sampling or testing a test hole or dewatering well, unless,
  - the installation of the equipment involves an alteration of the well, other than notching the top of the casing, or
  - the equipment is used to test the yield of the well or the aquifer.

  Examples of such equipment include: pressure transducers with dataloggers for monitoring and dedicated inertial pump tubing or bailers for sampling.

Well Technician Licence Exemption for Experienced Professionals

An experienced person who works for a licensed well contractor does not require a well technician licence for Class 5 activities (see Table 3-1 of this chapter) if the professional:

- holds a licence, limited licence or temporary licence under the *Professional Engineers Act*,
- holds a certificate of registration under the *Professional Geoscientists Act, 2000* and who is a practicing member, temporary member or limited member of the Association of Professional Geoscientists of Ontario, or
- is registered under Subsection 8 (2) of the *Ontario Association of Certified Engineering Technicians and Technologists Act, 1998*, being chapter Pr7, and who is an ordinary member of the Association continued under that Act.

When undertaking activities as described in Class 5, persons exempted from the Class 5 well technician licensing requirement must either be employed by a duly licensed well contractor, or be a holder of a well contractor licence.

Reminder: The requirement for a well contractor licence ensures that there is minimum liability insurance coverage and that experienced professionals are working at well construction activities. The licensed well contractor does not need to be on site when the exempted P. Eng, P. Geo or CET is undertaking Class 5 activities. See the "Requirements for Obtaining a Well Contractors Licence" section in this chapter for further information.

Abandonment

Abandonment of a well is not considered well construction. As a result, licensing requirements for the construction of a well do not apply to well abandonment and therefore obligations are placed on the person abandoning the well, often the well owner.

Obligation to Retain a Licensed Well Contractor

Unless exempted by the *Wells Regulation*, the person abandoning a well, often the well owner, must do the following:

- retain the services of a licensed well contractor, and
- ensure the contract with the well contractor contains a provision that the well technician who will do the abandonment work, is licensed to construct the same type of well as the one to be abandoned.

Exemption - Obligation to Retain a Licensed Well Contractor

The person abandoning the well is exempt from the above requirements if the person who works at the abandonment of the well is:

- the owner of the land or is a member of the owner's household,
- working without remuneration (e.g., not being paid) for another person on land owned by the other person or on land owned by a member of the other person's household, or
- a person who holds a Class 1 well technician licence (drilling).

Reminder: A separate manual has been prepared for test holes and dewatering wells titled Test Holes and Dewatering Wells: Requirements and Best Management Practices. Please refer to the other manual for information on additional exemptions to abandoning some test holes and dewatering wells.

Unattended
: Refers to the circumstance when the person working on a well is no longer in control of or watching the specific well. Examples of leaving the well unattended can include leaving the property, working on another well while not being present at the original well or not being in control of the well site.

Previously Installed
: Equipment found already to be installed into the well when arriving at the well is considered to be equipment that has been previously installed. Some monitoring equipment is allowed to be left unattended in wells because the equipment has been previously installed in the wells, for example, a pump and pumping equipment that have been installed in a well by a licensed well technician. The person can use the previously installed pump and pumping equipment to sample water from the well and be exempt from the licensing requirements in respect of sampling and monitoring in the *Ontario Water Resources Act*.

For the clarification of the terms "minor alteration" and "routine repair" see Chapter 2: Definitions and Clarifications Table 2-1 and Table 2-2 respectively.

Relevant Sections - Additional Regulations Or Lesgislation

Ontario Labour Mobility Act, 2009, S.O. 2009, c. 24

- *Ontario Water Resources Act*, R.S.O. 1990, Chapter 0.40 – Sections 35 to 50 inclusive

Table 3-1: Activities Permitted by Class of Well Technician Licence

Water Supply Wells

Activities	No Licence Required	Class 5 [*]	Class 4	Class 3 [**] (Driving/Jetting Wells Only)	Classes 1 & 2
Inspect well	the activity is permitted under specific circumstances and/or with restrictions • Must not leave equipment unattended	the activity is permitted	the activity is permitted	the activity is permitted under specific circumstances and/or with restrictions • Must not leave equipment unattended	the activity is permitted under specific circumstances and/or with restrictions • Must not leave equipment unattended

<table>
<tr><th>Activities</th><th>No Licence Required</th><th>Class 5 [*]</th><th>Class 4</th><th>Class 3 [**] (Driving/Jetting Wells Only)</th><th>Classes 1 & 2</th></tr>
<tr><td>Monitor, sample or test well</td><td>the activity is permitted under specific circumstances and/or with restrictions

the installation of an inertial lift pump is permitted
Must not leave equipment unattended or must use previously installed equipment
Equipment must not be used to test yield of well or aquifer</td><td>the activity is permitted under specific circumstances and/or with restrictions
Equipment must not be used to test yield of well or aquifer</td><td>the activity is permitted</td><td>the activity is permitted under specific circumstances and/or with restrictions
Must not leave equipment unattended or must use previously installed equipment
Equipment must not be used to test yield of well or aquifer</td><td>the activity is permitted under specific circumstances and/or with restrictions
Must not leave equipment unattended or must use previously installed equipment
Equipment must not be used to test yield of well or aquifer</td></tr>
<tr><td>Install pump (for purposes other than sampling)</td><td>the activity is not permitted</td><td>the activity is not permitted</td><td>the activity is permitted</td><td>the activity is not permitted</td><td>the activity is not permitted</td></tr>
<tr><td>Construct well</td><td>the activity is not permitted</td><td>the activity is not permitted</td><td>the activity is not permitted</td><td>the activity is permitted under specific circumstances and/or with restrictions
Driving or jetting only</td><td>the activity is permitted under specific circumstances and/or with restrictions
Class 1 – drilling only
Class 2 – digging or boring</td></tr>
<tr><td>Abandon well [***]</td><td>the activity is not permitted</td><td>the activity is not permitted</td><td>the activity is not permitted</td><td>the activity is permitted under specific circumstances and/or with restrictions
If well was driven or jetted</td><td>the activity is permitted under specific circumstances and/or with restrictions
Class 1 can abandon all wells
Class 2 can only adandon dug or bored wells</td></tr>
</table>

Test Holes & Dewatering Wells

Activities	No Licence Required	Class 5 [*]	Class 4	Class 3 [**] (Driving/Jetting Wells Only)	Classes 1 & 2

Activities	No Licence Required	Class 5 [*]	Class 4	Class 3 [**] (Driving/Jetting Wells Only)	Classes 1 & 2
Inspect well	the activity is permitted under specific circumstances and/or with restrictions • Must not leave equipment unattended	the activity is permitted	the activity is permitted	the activity is permitted under specific circumstances and/or with restrictions • Must not leave equipment unattended	the activity is permitted under specific circumstances and/or with restrictions • Must not leave equipment unattended
Install equipment to monitor, sample or test	the activity is permitted under specific circumstances and/or with restrictions the installation of an inertial lift pump is permitted • No alteration other than notching the top of casing • Equipment must not be used to test yield of well or aquifer	the activity is permitted	the activity is permitted	the activity is permitted under specific circumstances and/or with restrictions • No alteration other than notching the top of casing • Equipment must not be used to test yield of well or aquifer (the installation of an inertial lift pump is permitted)	the activity is permitted under specific circumstances and/or with restrictions the installation of an inertial lift pump is permitted • No alteration other than notching the top of casing • Equipment must not be used to test yield of well or aquifer
Install pump (for purposes other than sampling)	the activity is not permitted	the activity is permitted	the activity is permitted	the activity is not permitted	the activity is not permitted
Construct well	the activity is not permitted	the activity is permitted under specific circumstances and/or with restrictions • Only with non-powered equipment	the activity is not permitted	the activity is permitted under specific circumstances and/or with restrictions • Driving or jetting only	the activity is permitted under specific circumstances and/or with restrictions • Class 1 – drilling • Class 2 – digging or boring (augering)

Activities	No Licence Required	Class 5 [*]	Class 4	Class 3 [**] (Driving/Jetting Wells Only)	Classes 1 & 2
Abandon well [***]	the activity is not permitted	the activity is permitted under specific circumstances and/or with restrictions	the activity is not permitted • Only with non-powered equipment	the activity is permitted under specific circumstances and/or with restrictions • If well was driven or jetted	the activity is permitted under specific circumstances and/or with restrictions • Class 1 can abandon all wells • Class 2 can only abandon dug or bored wells

Reminder: Table 3-1 does not apply if the well is a shallow works test hole, shallow works dewatering well or another type of well exempted from the *Wells Regulation* and the pertinent licensing sections in the *Ontario Water Resources Act*

Reminder: A well technician licence or well contractor licence is not required if the person doing the construction or abandonment work is the owner of land, a member of the owner's household or works for free for the owner of the land.

Key Concepts

Well Contractor Licence

The *Wells Regulation* - No person shall engage in the business of well construction without a valid well contractor licence unless exempt under the *Wells Regulation*.

Construct
: When used with respect to a well, this means bore, dig, drill or otherwise make, extend or alter. Construct also includes installing equipment in or connected to a well (see Table 2-1 in Chapter 2: Definitions & Clarifications).

A well contractor licence authorizes the licence holder to operate a well construction business. A well contractor licence is issued to an applicant whose qualifications and financial responsibility meet the Ministry's requirements. A well contractor is responsible for holding the required insurance and for ensuring that the *Ontario Water Resources Act* and the *Wells Regulation* are complied with. To physically construct wells, a licensed well contractor must hold a well technician's licence or employ licensed well technicians.

Well Technician Licence - Different Classes

The *Wells Regulation* - No person shall work at the construction of a well without a valid well technician licence of a prescribed class unless exempt under the *Wells Regulation* or the *Ontario Water Resources Act*.

There are five classes of well technician licences which allow a person to perform different construction activities on a well. Four of the five classes (1, 2, 4 and 5) of licences represent common well construction activities using types of equipment or methods that are specified in the *Wells Regulation*. The other class of well technician licence, called Class 3, allows the Director to issue a licence for a specialized method or piece of well construction equipment. The well technician licence classes under the *Wells Regulation* are as follows:

Class 1 - Well Drilling

A licence authorizing the holder to construct and supervise the construction of wells by means of well drilling equipment including the following:

- Rotary drilling equipment (e.g., standard, dual rotary, reverse, air, mud and air percussion)
- Cable tool (e.g., churn drill and percussion drill)
- Diamond drilling equipment (e.g., rotary equipment used to construct wells that is commonly associated with mineral exploration)

Class 2 - Well Digging And Boring

A licence authorizing the holder to construct and supervise the construction of wells by means of digging with non-powered equipment or with a back-hoe or power shovel and by means of boring or augering equipment.

Class 3 - Other Well Construction

A licence authorizing the holder to construct and supervise the construction of wells, or a type of well described in the licence, by only the equipment or methods (e.g., sonic, direct push and rehabilitation) specified on the licence.

Class 4 - Pump Installation

A licence authorizing the holder to install or supervise the installation of pumps and related equipment in or connected to a well (e.g., installation of down the well systems for chlorination, pitless adapters and sanitary well seals).

A person, who is licensed as a class 4 well technician, can extend or shorten well casing, construct a well pit (if allowed, see Chapter 9: Equipment Installation) or remove a well pit as long as the activity involves the installation of a pump and its associated equipment.

For example, the above licence allows a person to do the following on a drilled well:

- Remove a well pit around the top of a drilled well and remove waterlines and related associated equipment from an existing drilled well.
- Weld a new piece of well casing from the top of the existing drilled well casing to more than 40 cm above the land surface.
- Create a new hole in the well casing and fit the hole with a pitless adapter connection.
- Connect a horizontal pipe and a drop pipe with a submersible pump to a pitless adapter.
- Backfill the well opening with a suitable sealant that must withstand the weight of humans and vehicles.

A Class 4 well technician licence also allows the holder to install pumps and associated equipment into both the taking well(s) and recharge well(s) of an open loop geothermal earth energy system.

Class 5 - Monitoring, Sampling, Testing And Non-Powered Construction

A licence authorizing the holder to do the following:

- Install and supervise the installation of monitoring, sampling or testing equipment in a well, other than equipment used to test the yield of the well or the aquifer,
- Install and supervise the installation of pumps in a test hole or dewatering well for monitoring, sampling or testing purposes, and
- Construct and supervise the construction of test holes and dewatering wells by any method that does not use powered equipment but
- not the construction of a well that is not a test hole or dewatering well by non-powered equipment activities.

Reminder: A person who holds a Class 4 licence can perform and supervise the equipment installation activities found in the Class 5 licence but not the construction of a well by non-powered equipment activities. A person who holds a Class 1 or Class 2 licence can do and supervise the non powered construction activities found in the Class 5 licence but not the installation activities.

In many cases, activities such as sampling well water or measuring water levels or installing sampling, monitoring and testing equipment in a water supply well are exempt from the Wells section of the *Ontario Water Resources Act* and the *Wells Regulation*. See the “Exemptions – Construction Activities” in the Plainly Stated section of this chapter and the “Exempted Construction Activities and Licensing for All Wells” section in this chapter.

The following are examples of activities for which a Class 5 licence is required:

- Installing permanent monitoring equipment in a municipal or domestic well where a pumping or yield test is not being performed.
- Installing a pump and associated pumping equipment in a test hole or dewatering well to test the yield of the well or the aquifer.
- Constructing a test hole and dewatering well without the use of powered equipment if the shallow works exemption does not apply.

Reminder: There is an exemption from Class 5 licensing requirements for experienced, qualified professionals that are either employed by a duly licensed well contractor or are a holder of a well contractor licence (see the “Persons Exempted from Class 5 Licensing” section of this chapter).

Well Technician Licensing Examples:

If a person is undertaking work covered by various classes of licence, for example digging a well and installing a pump, then the person would require a licence with Class 2 and Class 4.

If a person only has a Class 1 licence, the person cannot construct a dug well or install a pump. S/he would require a licence with Class 2 and Class 4 to do both of these activities.

Exemptions From Well Technician Licence

Individual Land Owners And Their Families

- on land owned by the person or by a member of the person's household; or
- for another person on land owned by the other person or by a member of the other person's household without remuneration or financial exchange.

Individual land owners and their families can work on wells on their own properties as long as no remuneration or financial exchange occurs. If the land owner is a business (corporation, partnership, sole proprietor) or a provincial government agency, an employee must have a proper well technician licence to construct a well and the business or government agency must have a well contractor licence.

Exempted Construction Activities And Licensing For all Wells

The *Wells Regulation* - The following well construction activities are exempt from the *Wells Regulation* requirements and the person doing these activities is exempt from the licensing requirements under the *Ontario Water Resources Act* (s. 36 to 50):

- Inspecting the well using equipment (e.g., video camera) that is not left unattended in the well.
- Monitoring (e.g., water level indicator), sampling (e.g. small submersible pump, inertial lift pump), or testing (e.g., conductivity, DO and pH meters) the well using equipment that is not used to test the yield of the well or the aquifer and:
  - the equipment is not left unattended in the well, or
  - the equipment was previously installed in the well.

Examples

If a person uses a water level meter solely to measure the water level in the well or the depth of the well, the well licensing and construction requirements of the *Ontario Water Resources Act* and *Wells Regulation* do not apply.

The well licensing and construction requirements of the *Ontario Water Resources Act* and *Wells Regulation* apply to the use of a water level meter when conducting a test of the well yield.

If an unlicensed person collects water samples and water level data using sampling and monitoring equipment in a water supply well, s/he may take samples and measurements on the well without holding a well technician licence and the well construction requirements of the *Ontario Water Resources Act* and the *Wells Regulation* do not apply.

Reminder: There are additional exempted well construction activities and licensing for "test holes" and "dewatering wells" as defined in the *Wells Regulation*. See section 1.0.2 of the *Wells Regulation* or Chapter 3 of the Test Holes and Dewatering Wells – Requirements and Best Management Practices for further information.

Person Abandoning The Well

The person abandoning the well (often the well owner) is required to retain the services of a licensed well contractor for any well abandonment operation unless otherwise exempt under the *Wells Regulation*. For example, individual land owners and their families can work at the abandonment of wells on their own property as long as no remuneration or financial exchange occurs.

For additional information see the "Responsibilities of the Person Abandoning the Well For Abandonment Operations" section in this chapter.

Best Management Practice – Retain Experienced and Licensed Professionals to Construct and Alter a Well and Properly Abandon (Plug and Seal) a Well

Although the *Ontario Water Resources Act* and the *Wells Regulation* allow residential well owners to construct or abandon their own wells without a licence, the equipment, materials and expertise needed to comply with the requirements under the *Wells Regulation* can exceed the average well owner's abilities and resources. Well owners need to understand how to measure water levels and well depths and be able to calculate volumes of well water, chemical mixtures and material mixtures. For instance, if a

residential well owner cannot properly calculate and mix chemicals, does not have the necessary equipment or cannot employ proper safety procedures s/he should not construct a well. If the owner did the work, then s/he would be responsible for meeting all of the requirements of the *Wells Regulation*. A skilled well technician with valid well technician licenses of the correct class, working for a well contractor with a valid well contractor licence, should be retained to construct or abandon any well.

Licensing Requirements

Requirements For Obtaining Licences

Licensing requirements are set out in the *Wells Regulation* as follows:

- Requirements and obligations for a well contractor licence (Sections 2, 3, 4)
- Requirements and obligations for a well technician licence (Sections 5, 6, 6.1, 7)
- Examination process for a well contractor licence and a well technician licence (Section 8)
- Continuing Education requirements for well technicians (Section 8.1)
- Requirements for an assistant well technician (Section 9)

Requirements For Obtaining A Well Contractor Licence

To obtain a well contractor licence, an applicant must:

- Submit application forms for the licence and examination and pay the applicable fees. The licence application requires the inclusion of a list of employees who:
    - have a well technician licence,
    - have applied for a well technician licence or
    - are experienced professionals exempted by the *Wells Regulation*.
- Designate at least one official representative of the company. The designated person(s) is (are) responsible to ensure that the *Ontario Water Resources Act* and *Wells Regulation* are complied with.
- Be a minimum of age of 18 years. If the applicant is a partnership or a corporation, a partner or director of the entity must be a minimum age of 18 years.
- Hold minimum insurance in a form approved by the Superintendent of Insurance that includes:
    - $2,000,000 or more for property damage arising out of any one incident, and
    - $2,000,000 or more for the death of or bodily injury to any person who is not an employee of the licensee, for each such person.

  The Contract of insurance may:

    - Limit the insurer's liability under the contract of insurance arising out of any one incident to $5,000,000, and
    - Provide that the insured is responsible for a set amount, up to $1,000 for each claim for which coverage is required.
- Submit the following supporting documentation that the Director requires in conjunction with the licence application:
    - Proof of insurance, and
    - Copy of business licence or proof of incorporation.
- Pass a Ministry examination with a minimum grade of 75% (the examination includes relevant sections of the *Wells Regulation* and the *Ontario Water Resources Act*. The examination must be taken and passed by each official representative of the company.
- Provide additional information as may be required by the Director.

Reminder: The well contractor licence applicant is not required to take training courses, but is required to pass a Ministry exam, have an official representative and hold valid insurance. In the event the business is a sole proprietorship (with single owner/operator) the owner is also required to obtain and maintain a valid well technician licence of a prescribed class (see requirements below) unless otherwise exempt under the *Wells Regulation*.

Responsibilities Of A Well Contractor Licence Holder

The responsibilities of a well contractor licence holder are to:

- Ensure at least one director, officer or partner is designated as the official representative of the licensee at all times, if the licence holder is a corporation or partnership. The official representative must be assigned the responsibility of ensuring that the *Wells Regulation* and the *Ontario Water Resources Act* are complied with.
- Possess and maintain the appropriate insurance as outlined above.
- Employ the appropriately licensed well technicians and/or licensed professionals.
- Ensure that the well technicians, other employees and agents comply with the requirements of the *Wells Regulation*, the *Ontario Water Resources Act* and any other applicable provincial legislation relevant to constructing a well.
- Submit a well contractor licence renewal application form, required information such as insurance and fee to renew the licence by March 31 of each year.
- Report in writing, any change to information previously provided to the Ministry in relation to the licence to the Director within ten (10) days of the change.

Requirements For Obtaining A Well Technician Licence (Class 1,2,3 or 4)

To obtain a well technician licence (Class 1, 2, 3 or 4), a person must:

- Submit application forms for the licence and examination and pay the applicable fees.
- Successfully complete a course of study of at least 30 hours approved by the Ministry of the Environment and Climate Change. The applicant must provide a transcript to the Ministry along with a completed application for the particular class of licence applied for.

- Demonstrate:

  - 4,000 hours of experience in the field working on well construction projects or helping at projects which must be relevant to the class of licence applied for (e.g., construction of wells by means of well drilling equipment for a Class 1 licence, or installing or assisting with pump installation in or connected to a well for Class 4 licence), or
  - A combination of experience and other qualifications (e.g., licence from another province or jurisdiction, an approved degree or courses from a University or College) that the Director considers equivalent to 4,000 hours of experience. For example, if another type of certification or education is held (e.g., pipe fitter licence, welding or electrical certificate or the 2 year Drilling and Blasting course at Fleming College) the full 4000 hours might not be required at the discretion of the Director.
- Be a minimum age of 18 years.
- Pass a Ministry examination with a grade of 75% (the examination includes relevant sections of the *Wells Regulation* and the *Ontario Water Resources Act*).
- Provide additional information as may be required by the Director. For example, letters of reference are typically required to satisfy the Director as to the applicant's character, qualifications and ability.

Requirements For Obtaining A Well Technician Well Technician Licence (Class 5)

If the applicant is:

- a member of the Association of Professional Engineers of Ontario as an engineer-in-training (EIT),
- a member of the Association of Professional Geoscientists of Ontario as a geoscientist-in-training (GIT), or
- a member of the Ontario Association of Certified Engineering Technicians and Technologists as a technician or technologist-in-training (CTIT)

Then s/he must:

- Submit the application form and pay the applicable licence fee.
- Successfully complete a course of study of at least 15 hours approved by the Ministry of the Environment and Climate Change.

- Have:

  - 500 hours of experience in the field helping at or doing the activity that would be authorized by the Class 5 licence, or
  - a combination of experience and other qualifications (e.g., a licence from another province or jurisdiction, an approved degree or courses from a university or college) that the Director considers equivalent to 500 hours of experience.
- Be a minimum age (18 years).
- Pass a Ministry examination with a minimum grade of 75% (the examination includes relevant sections of the *Wells Regulation* and the *Ontario Water Resources Act*).

Reminder: For additional information on the application process including formal education and training on licensing see the contact information in the "Tools for Well Construction Licences" section at the end of this chapter.

If the applicant is anyone other than an EIT, GIT or CTIT, s/he must:

- Submit the application form and pay the applicable licence fee.
- Successfully complete a course of study of at least 30 hours approved by the Ministry of the Environment.
- Have:
  - 1,000 hours of experience in the field helping at or doing the activity that would be authorized by the Class 5 licence, or
  - a combination of experience and other qualifications (e.g., a licence from another province or jurisdiction, an approved degree or courses from a University or College) that the Director considers equivalent to 1,000 hours of experience.
- Be a minimum age (18 years).
- Pass a Ministry examination with a minimum grade of 75% or better (the examination includes relevant sections of the *Wells Regulation* and the *Ontario Water Resources Act*).

Persons Exempted From Class 5 Licensing

The following persons may do work or supervise all construction activities described in a class 5 licence without a well technician licence if s/he works for a person who holds a well contractor licence or is himself or herself a holder of a well contractor licence:

- A person who holds a licence, temporary licence or limited licence under the *Professional Engineers Act*;
- a person who holds a certificate of registration under the of *Professional Geoscientists Act, 2000* and who is a practicing, temporary or limited member of the Association of Professional Geoscientists of Ontario (APGO); or
- a person who is registered under subsection 8 (2) of the *Ontario Association of Certified Engineering Technicians and Technologists Act, 1998* and who is an ordinary member of the Ontario Association of Certified Engineering Technicians and Technologists (OACETT).

The requirement for a well contractor licence ensures that there is minimum liability insurance coverage and qualified professionals are working at well construction activities. The licensed well contractor does not need to be on site when the exempted professional P.Eng, P.Geo or CET is undertaking Class 5 activities.

Reminder: An exempted professional [e.g., Professional Engineer (P.Eng), Professional Geoscientist (P.Geo), and Certified Engineering Technologist (CET)] who does not hold a well technician licence, but who works for a holder of a well contractor licence can only supervise a person who is conducting well construction activities associated with a Class 5 well technician licence if the supervised person:

- is an exempted professional or
- holds a valid Class 5 well technician licence.

Reminder: If the exempted professional intends to supervise an "assistant well technician", the exempted professional must hold the correct class of well technician licence.

Reminder: A person who holds a class 4 licence can perform and supervise the equipment installation activities found in the Class 5 licence but not the construction of a well by non-powered equipment activities. A person who holds a class 1 or 2 licence can perform and supervise the non-powered construction activities found in the Class 5 licence, but not the installation activities.

Requirements For Obtaining A Well Technician Licence: Out-Of-Province Applicants

The *Ontario Labour Mobility Act, 2009*, S.O. 2009, c. 24 provides that individuals certified in another Canadian jurisdiction will not have to complete any additional "material" requirements to obtain a well technician licence in Ontario.

A person who currently holds a valid licence in another Canadian province or territory is required to provide:

- A copy of all current and valid licences held in any other jurisdiction regarding well construction.
- Letters of reference from the licence issuance authority in each jurisdiction where any current and valid licence is held that contains a complete licensing history regarding the applicant and their well construction history in that jurisdiction. The letter must include information about the types of well construction equipment operated, types of wells constructed, numbers of wells constructed annually for the past 5 years, numbers of pumps installed and information regarding complaints, compliance and enforcement.
- Additional information that may be required to satisfy the Director as to the applicant's character, qualifications and ability. For example, a preliminary discussion with the licensing applicant may be required to review the information provided by the applicant. Subsequent to that discussion with the ministry, additional information or discussions may be required to address any outstanding issues.
- A completed Application for a Well Contractor Licence and a completed Application for a Well Technician Licence. If the applicant will be working for a company that already holds a valid Well Contractor Licence in Ontario, then s/he is required to provide that well contractor licence number.

- A completed Application to Take an Examination (based on Ontario well construction requirements) with the required fees will also be required. In preparation for the required examination, the applicant should be familiar with the *Ontario Water Resources Act*, including sections 1, 34 to 52, and the *Wells Regulation*, *Regulation 903* as amended, made under the *Ontario Water Resources Act*.

Reminder: A person who is currently licensed for well construction in another Canadian province or territory may contact the Ontario Ministry of the Environment and Climate Change at or wellshelpdesk@ontario.ca, or for assistance and information on how to obtain a licence for well construction in Ontario.

Reminder: Any person applying for a well contractor licence has the same requirements irrespective of his/her current licensing status in another jurisdiction (see the Requirements for Obtaining a Well Contractor Licence section on this chapter).

Reminder: For additional information regarding the *Ontario Labour Mobility Act, 2009*, S.O. 2009, c. 24 or the *Ontario Water Resources Act*, or R.R.O. *Regulation 903*, please refer to: Ontario e-laws website and Ontario Ministry of Advanced Education and Skills Development website.

Responsibilities Of A Well Technician Licence Holder

The responsibilities of a Well Technician Licence Holder are to:

- Ensure that s/he works for a licensed well contractor or a provincial Ministry of the Crown.
- Ensure that s/he and any person under his/her supervision meet the requirements of the *Wells Regulation*, the *Ontario Water Resources Act* and any other applicable provincial legislation relevant to constructing a well.
- Ensure that s/he only works or supervises work as specifically authorized by the well technician licence that s/he holds.
- Ensure that s/he only supervises up to two pieces of well construction equipment at any one time. This number refers to the pieces of equipment and not necessarily the number of people a well technician can supervise.
- Have his/her well technician licence or a photocopy of the entire licence onsite at all times during well construction activities and produce it upon request of an employee or agent of the Ministry.
- Report, in writing, any change to information previously provided to the Ministry in relation to the licence to the Director within ten (10) days of the change.
- Submit an application form and the required fee to renew the licence by March 31 of each year.
- Return any assistant well technician identification card immediately to the Ministry, when s/he becomes a well technician.
- Successfully complete continuing education courses. After a new licence has been renewed for the first time, a minimum of 21 hours of Ministry approved continuing education courses must be taken every 3 years in order to renew a well technician licence that is identified as Class 1 to Class 4. Similarly, after a licence has been renewed for the first time, a minimum of 14 hours of Ministry approved continuing education courses must be taken every 3 years in order to renew a well technician licence that is identified as a Class 5.

Continuing Education For A Well Technician Licence Holder

For the purposes of the three (3) year continuing education course cycle, which starts the year of the first renewal, the applicant must successfully complete the Director approved courses within a period of time that:

- ends on the date the licence renewal application is submitted, and

- begins on the later of either:

    - January 1, three years prior to the year of licence renewal, or
    - the final day of instruction in a course that previously counted towards the continuing education requirement for a previous licence renewal and the course occurred in the calendar year three years before the licence renewal application is submitted.

The following provides examples:

1. A Class 1 well technician (driller), originally licensed in 2006, will renew the licence for the first time in 2007. The well technician must take a course or courses that are approved by the Director, totalling at least 21 hours, and prior to the 2010 licence renewal. In this example, the period for the continuing education started January 1, 2007. The last course must be successfully completed before the well technician submits the 2010 well technician licence application to the Director.
2. The same Class 1 well technician (driller), who applies for licence renewal in 2013, must take a course or courses, approved by the Director, totalling at least 21 hours prior to the 2013 licence renewal. In this example, the period for the continuing education starts January 1, 2010. The last course must be successfully completed before the well technician submits the 2013 well technician licence application to the Director.

3. The same Class 1 well technician (driller), who is applying for licence renewal in 2013, must take a course or courses, approved by the Director, totaling at least 21 hours prior to the 2013 licence renewal. The well technician took a:
    - 3-day course that started January 21, 2010 and ended January 23, 2010,
    - 2-day course that started February 1, 2010 and ended February 2, 2010,
    - 3-day course that started March 3, 2010 and ended March 5, 2010,
    - 2-day course that started March 3, 2012 and ended March 5, 2012, and
    - 1-day course on February 4, 2013.

In this example, the well technician counted the time for the January 21 to 23 and February 1 to 2, 2010 courses for a previous 2007 to 2010 continuing education cycle. The well technician did not count the time for the March 3 to 5, 2010 course for the previous 2007 to 2010 education cycle.

In this example, the 2010 to 2013 period for the continuing education could start January 23, 2010 (i.e., the last day of a course of instruction three years prior to the licence renewal) because the course was used for a previous continuing education cycle. This allows the well technician to use the hours obtained in the final day of the January course to count towards the 2010 to 2013 continuing education period. The February and March 2010, March 2012 and February 2013 courses can also be used by the well technician for the 2010 to 2013 continuing education period. The last course must be successfully completed before the well technician submits the 2013 well technician licence application to the Director.

Reminder: In the case of a class 5 well technician licence, the minimum continuing education hours total at least 14 instead of 21 hours.

Reminder: All well technician applications must be submitted to the Director before March 31 of each year in order for the licence to be continued after March 31 pending the Director's decision.

Continuing education courses are currently available through Fleming College and the Ontario Groundwater Association regional meetings. The Director has the discretion to approve other courses and set the criteria used to approve other courses.

Best Management Practice – Taking Additional Courses

To further his or her education, continued knowledge of environmental requirements and technological advances, a licensed well technician should take more than the minimum number of continuing education hours on topics that are directly related to the activities the technician performs on a well.

Responsibilities Of The Person Abandoning The Well For Abandonment Operations

Reminder: Abandonment of a well is not considered well construction. As a result, licensing requirements for the construction of a well do not apply to well abandonment and therefore obligations are placed on the person abandoning the well, often the well owner

Obligation To Retain A Licensed Well Contractor

Unless exempt by the *Wells Regulation*, when a well is abandoned, the person abandoning a well (often the well owner) must do the following:

- Retain the services of a licensed well contractor, and
- Ensure the contract with the licensed well contractor requires a well technician licensed to construct the type of well being abandoned is used to abandon the well.

Exemption - Obligation To Retain A Licensed Well Contractor

The person abandoning the well is exempt from the above requirement if the person who works at the abandonment of the well is:

- the owner of the land or is a member of the owner's household,
- working without remuneration (e.g., not being paid) for another person on land owned by the other person or on land owned by a member of the other person's household, or
- a person who holds a Class 1 well technician licence (i.e., drilling) see the "Responsibilities of a Licensed Well Technician" section of this chapter.

Excavation Of Entire Test Hole Or Dewatering Well

Reminder: Unless exempted, the person abandoning the well, often the well owner, must meet the requirements in the "Responsibilities of the Person Abandoning the Well For Abandonment Operations" section, even if the well is to be fully excavated.

Reminder: This does not apply if the well is a shallow works test hole, shallow works dewatering well or another type of well exempted from the *Wells Regulation* and the pertinent licensing sections in the *Ontario Water Resources Act* (see the "Plainly Stated" section in Chapter 3: Exemptions: Wells, Activities & Exempted Professionals)

A person can abandon a well before it is completely excavated. In this case, the person abandoning the well, often the well owner, must ensure that the "Obligation to Retain a Licensed Well Contractor" or the "Exemption - Obligation to Retain a Licensed Well Contractor" sections in this chapter are followed.

Examples

Examples of types of individuals that can work on the abandonment of a well for the person abandoning the well to meet his/her obligations are as follows:

- A person who holds a valid Class 1 well technician licence can work at the abandonment of a well constructed by drilling equipment.
- A person who holds a valid Class 1 well technician licence can work at the abandonment of a well constructed by digging or excavation equipment (see the "Responsibilities of a Licensed Well Technician" section of this chapter).

- For a well constructed by drilling equipment within a well originally constructed by digging or boring equipment (e.g., dug well or well pit):

  - A person who holds a valid Class 1 well technician licence can work at the abandonment of the well or
  - A person who holds a valid Class 2 well technician licence and holds or works for the holder of a well contractor licence can work at the abandonment of the dug portion of the well, or well pit, and the drilled portion can be abandoned by a person who holds a valid Class 1 well technician licence. Both portions of the well must be properly abandoned.

- For a well constructed by jetting or driving equipment within a well originally constructed by digging or boring equipment (e.g., dug well or well pit):

  - A person who holds a valid Class 1 well technician licence can work at the abandonment of the well or
  - A person who holds a valid Class 2 well technician licence can work at the abandonment of the dug portion of the well, or well pit and a person who holds a valid Class 3 well technician licence that allows him/her to construct driven/jetted wells can abandon the driven/jetted portion. Both persons must hold or work for the holder of a well contractor licence. Both portions of the well must be properly abandoned.
- A person who holds a valid Class 2 well technician licence and holds or works for the holder of a well contractor licence can work at the abandonment of a well constructed by digging or excavation equipment.
- A person who holds a valid Class 3 well technician licence that authorizes the holder to construct wells and holds or works for the holder of a well contractor licence can work at the abandonment of a well originally constructed as specified on the well technician licence.
- A person who holds a valid Class 3 well technician licence that authorizes the holder to construct wells and holds or works for the holder of a well contractor licence can work at the abandonment of a well originally constructed as specified on the well technician licence.

Reminder: See Chapter 13: Well Records, Documentation, Reporting & Tagging for further information on the person abandoning the well.

Reminder: A separate manual has been prepared for test holes and dewatering wells titled Test Holes and Dewatering Wells - Requirements and Best Management Practices. Please refer to the other manual for information on additional exemptions to abandoning some test holes and dewatering wells.

Requirements for an Assistant Well Technician

Assistant Well Technician With No Identification Card

An assistant well technician without an identification card is exempt from requiring a well technician licence if the assistant well technician is supervised by a holder of a well technician licence, of the correct class of licence for the well construction activity, who is present at the site at all times.

Assistant Well Technician With Identification Card

An assistant well technician with an identification card is exempt from requiring a well technician licence when working at the construction of wells on behalf of the licensed well contractor named on the card if:

- the expiry date on the card has not yet been reached,
- s/he carries the card and produces it on the request of an employee or agent of the Ministry, and
- s/he is supervised by the holder of a valid well technician licence, of the correct class of licence for the well construction activity, who is available to be called to the site within one hour.

Requirements for Obtainnig an Assistant Well Technician Card

The requirements for obtaining an assistant well technician card are as follows:

- A licensed well contractor can apply to the Ministry for an identification card for an assistant well technician who has worked for the business a minimum of four (4) months.
- A licensed well contractor can apply to the Ministry for a new identification card for the assistant well technician if the card is about to expire.

Reminder: There is no minimum age requirement for an assistant well technician or for obtaining an identification card set out in the *Wells Regulation*. However, employers must meet all applicable labour laws when employing assistant well technicians.

Requirements of an Assistant Well Technician Identification Card

The requirements of an assistant well technician identification card are as follows:

- An identification card issued to an assistant well technician has an expiry date that is not more than 36 months after the date of issue.
- An identification card issued to an assistant well technician has an expiry date that is not more than 36 months after the date of issue.
- An identification card must be returned by the holder of the identification card immediately, to the Ministry, if the holder obtains a well technician licence. *Ontario Water Resources Act* – Grounds to Refuse New and Renewal Well Technician and Well Contractor Licence Applications

Grounds for Refusal to Issue a New Well Contractor Licence (excerpted from Section 41 of the *Ontario Water Resources Act*)

A Director may refuse to issue a well contractor licence for the following reasons:

a. The past conduct of the applicant or, where the applicant is a corporation, of its officers or directors indicates that the business of constructing wells will not be operated in accordance with the law and with honesty and integrity,
b. The applicant or, where the applicant is a corporation, its officers or directors are not competent to engage in the business of constructing wells,
c. The applicant is not in a position to observe or carry out the provisions of Sections 35 to 50 of the *Ontario Water Resources Act*, the *Wells Regulation* or the licence, or
d. The applicant or, where the applicant is a corporation, its officers or directors have been grossly negligent in carrying on the business of constructing wells under the authority of a licence issued under section 40 of the *Ontario Water Resources Act* or a predecessor of that section.

Grounds for Refusal to Renew a Well Contractor Licence (excerpted from Section 42 of the *Ontario Water Resources Act*)

A Director may revoke or suspend or may refuse to renew a well contractor licence for the following reasons:

a. Any person has made a false statement in any material part of the application for the licence or a renewal of the licence or of any report, document or other information,
b. The past conduct of the licensee or, where the licensee is a corporation, of its officers or directors is grounds to believe that the business of constructing wells has not been operated or will not be operated in accordance with the law and with honesty and integrity,
c. The licensee is in breach of sections 35 to 50 of the *Ontario Water Resources Act* or the *Wells Regulation*,
d. A change in the officers or directors of a corporation that is a licensee provides grounds for refusing to issue a licence,
e. The services that can be provided by the licensee have been misrepresented,
f. The licensee is not competent to carry on or has been grossly negligent in carrying on the business of constructing wells, or

g. The licensee is not in a position to observe or carry out the provisions of sections 35 to 50 of the *Ontario Water Resources Act*, the *Wells Regulation* or the licence.

Grounds for Refusal to Issue a New Well Technician Licence (excerpted from Section 45 of the *Ontario Water Resource Act*)

A Director may refuse to issue a well technician licence where the Director is of the opinion, upon reasonable and probable grounds, that the applicant is not competent to carry on the activities that would be authorized by the licence.

Grounds for Refusal to Renew a Well Technician Licence (excerpted from Section 46 of the *Ontario Water Resource Act*)

A Director may revoke or suspend or may refuse to renew a well technician licence where the Director is of the opinion, upon reasonable and probable grounds, that:

a. Any person has made a false statement in any material part of the application for the licence or a renewal of the licence or of any report, document or other information required,
b. The licensee is in breach of sections 35 to 50 of the *Ontario Water Resources Act* or the *Wells Regulation*, or
c. The licensee is not competent to carry on or has been grossly negligent in carrying on the activities that are authorized by the licence.

Tools for Well Construction Licences

Well Industry Licensing

The following is intended as a brief guide for applicants to summarize the application submission process for a **new Well Contractor Licence and/or Well Technician Licence including applications to add a class to an existing Well Technician Licence.**

Ontario Regulation 903 under the *Ontario Water Resources Act* prescribes licensing requirements for activities associated with wells. If you require a copy of *Regulation 903* or the relevant sections (35 to 50) of the *Ontario Water Resources Act*, please contact the Ministry's Public Information Centre at or or visit Ontario e-laws website (type “wells” in the search bar).

A Well Contractor Licence is a business licence and entitles the holder to engage in the business of well construction only. It does not authorize the holder to work at the construction of wells. The actual work is required to be carried out by a licensed Well Technician with a valid licence of the proper prescribed class(es). Well Technicians are required to work under the authority of a Well Contractor Licence holder. Both licences are required for anyone who is both an owner of a well construction business and also the sole equipment operator of that well construction business.

The licences expire on March 31 follwing the year of issue. In order to renew the licence(s) and ensure continuation, a renewal application package must be submitted (application form, applicable fees, required documentation) prior to the expiry of the licence. The water well industry licensing application forms are available on the Government of Ontario Central Forms Website (type “wells” in the search bar).

Every application (new or renewal) is reviewed in accordance with the Regulation and the approval of the application is dependent on the proper submission of all of the required information. Any requests or changes to the appliaction file should be provided in writing.

It is an offence to provide false information on any application form or statement with respect to any matter made under the Act, or the regulations.

Well Contractor Licence:

1. Application for Well Contractor Licence (Form 1 - 1987) - completed in full, dated and signed

2. Confirmation of valid Comprehensive General Liability Insurance as prescribed in the *Reg. 903* for the duration of the licence period for well construction business:

    - Name of the Insured(as per the Insurance Policy)
    - Policy No.
    - Expiry Date(YYYY/MM/DD)
    - Name of Insurance Company
    - Name of Insurance Agent
    - Description of Insured Activities

- Amount of Coverage

3. Copy of a valid Master Business Licence (MBL) or Proof of Incorporation - the Well Contractor Licence to be issued name of the insured operation. For details on how to register/renew your MBL, visit [Ministry of Government and Consumer Services website] (Services for Business / Gateway for Business) or contract Service Ontario Toll Free at . Note: MBL has to be renewed every five years.
4. Successful completion of **MOECC Exam**, see MOECC Examination for details
5. Payment of applicable fees, see **required fees** for details.

note: In case of partnerships and/or corporations, the official representative(s) designated for the Well Contractor as listed on the application must be a director, officer, or partner and be listed on the application for a Well Contractor Licence as well as on the official documentation i.e. Articles of Incorporation or Master Business Licence. Each designated official(s) must successfully complete the MOECC examination.

Well Technician Licence(new, add-a-class):

1. Application for Well Technician Licence (Form 4 - 1993) - completed in full, fated and signed
2. Proof of Successful Completion of an approved Course of Study, for course information visit [Fleming College website] or call . The pre-registration number is issued by MOECC upon request(in writing).

3. Supporting information to substantiate relevant work experience as prescribed in the *Reg. 903*. Please consult *Reg. 903* on number of hours of experience required. Information/documentation is required detailing nature of the work and how it qualifies the applicant for applicant for the licence and class(-es); and to clarify and/or detail the number of hours spent performing the activities, including any applicable overtime or additiaonal employers where experience might have been gained. Memoranda or letters of reference from current or past employers (and/or clients for self-employed) should be provided stating in detail;

   - dates of employment including type of employment(full- / part-time, hours) and name(s) of employer(s)/well contractor(s);

   - Duties and responsibilities relating to the licence and class(-es) requested:

     - **Class 1 - Well Drilling** (construction/ abandonment of wells by means of well drilling equipment including: rotary drilling equipment, cable tool and diamond drilling);
     - **Class 2 - Well Digging and Boring** (contruction/ abandonment of wells by means of digging with non-powered equipment or with a back-hoe or power shovel and by means of boring or augering equipment);
     - **Class 3 - Other Well Construction: please specify** (type of equipment operated/ installed/ repaired/ methods, etc.);
     - **Class 4 - Pump Installation** (installing or assisting with pump installation in or connected to a well, type or equipment operated/ installed/repaired);
     - **Class 5 - Monitoring, Sampling, Testing and non-Powered Construction** (installing or assisting with installation of; monitoring, sampling, tseting equipment in a well; pump in a test hole or dewatering well; constructing or assisting with constructiong of test holes, dewatering wells by non-powered equipment);
   - consent/permission to contract the individual(s) who supervised the work;
   - copies of well records, if completed/applicable.
4. Successful completion of MOECC Exam, see MOECC Examination for details
5. Payment of applicable fees, see **required fees** for details

note: Requirement for Class 5 applications - Proof of Association Membership, if applicable

MOECC Examination:

1. Application for An Appointment to Take An Examination (Form 7 - 1990) - completed in full, dated and signed
2. Successful completion of MOECC Exam
3. Payment of applicable fees, see **required fees** for details

Required Fees(Cheque or money order, Payable to “Treasurer of Ontario”);

1. Well Contractor Licence Application Fee: $10.00
2. Well Technician Licence application with on Class plus an additional $5 for each additional Class.
3. Examination Fee: $10.00

An administrative fee of $35.00 applies for any dishonored cheque payments including post-dated cheques.

Please direct any licensing inquiries/application package to the water well help desk as indicated on the applications forms.

4. Siting the Well

Chapter Description

Identifying the appropriate location for well construction will dictate the success or failure of any construction activity. Whether the goal is to find a water supply for potable, agricultural or industrial purposes, a comprehensive planning process will assist in identifying the right site for the well. This chapter provides guidance and minimum requirements for siting a well.

Regulatory Requirements - Well Siting

Relevant Sections - The *Wells Regulation*

- Location of Wells - Section 12(1) - (6)
- Records - Single Well Record - Section 16.3

The Requirements - Plainly Stated

The *Wells Regulation* requires the person constructing the well to meet the following when siting a well:

Anyone constructing a new well, other than a test hole or dewatering well, must follow all requirements for siting a well in the *Wells Regulation*.

The site of a new well must meet the minimum horizontal separation distances from contaminant sources that are provided in Table 4-1 and Table 4-2; and

Once a well has been constructed, the well location must be determined and indicated on the well record using a global positioning system (GPS) receiver, according to the instructions on the well record.

Table 4-1: Minimum Horizontal Separation Distances between Wells and Existing Sewage Systems [*]

Sewage System	Well with watertight casing to a depth of ≥ 6m (19.7 ft)	Any other well [1]
earth pit privy	15m (50ft)	30m (100ft)
privy vault, pail privy	10m (33ft)	15m (50ft)
greywater system	10m (33ft)	15m (50ft)
cesspool	30m (100ft)	60m (200ft)
treatment units (such as a septic tank)	15m (50ft)	15m (50ft)
distribution pipe in a leaching or filter bed	15m (50ft)	30m (100ft)
holding tank	15m (50ft)	15m (50ft)

These separation distances apply to any future earth pit privy, privy vault, pail privy, greywater system or cesspool, and a treatment unit, a distribution pipe in a leaching or filter bed, septic tank or holding tanks that has not been constructed but for which a building permit has been issued.

Table 4-2: Minimum Horizontal Separation Distances between Wells and Sources of Contaminants Other Than Those Mentioned in Table 4-1

	Drilled Well with watertight casing that extends to a depth of more than 6 m (19.7ft)	Any other well [1]
source of contaminants	15 m (50ft)	30 m (100ft)

Accessibility and Elevation

A person constructing a new well, other than a test hole or dewatering well, as defined in the *Wells Regulation*, must locate (site) a new well so that it is:

- accessible for cleaning, treatment, repair, testing, inspection and visual examination at all times before, during and after completion of construction of the well; and
- at a higher elevation than the immediate surrounding area.

Relevant Sections - Additional Regulations Or Legislation

Ontario Regulation 332/12 (Building Code) made under the *Building Code Act, 1992* - Tables 8.2.1.5, 8.2.1.6A, 8.2.1.6B and 8.2.1.6C

Key Concepts

What to Consider When Siting A Well

Many different factors must be taken into account before choosing where to place or site the well, including the following:

- Natural elements - such as the topography (land surface) of the site, the flow of groundwater, or the location of the aquifer
- Potential sources of contamination - septic systems, chemical storage (see Chapter 2: Definitions & Clarifications, Table 2-2 “contaminant” for further clarification)
- Safety - presence of overhead power lines or buried utilities

Important Information To Know

The list below includes most, but not all of the information and tools that may be needed to help in the planning and siting of the well:

- Size and shape of the property, property elevations – a diagram or simple map – measuring tools as needed
- Location of natural features – trees, topography, etc.
- Location of all nearby surface water sources such as lakes, rivers and creeks
- Location of springs
- Diagram of the property indicating the slope and contours of land to help determine possible direction of the groundwater flow
- Location or planned location of structures and their purposes – barn, storage shed, house, etc.
- Location or planned location of septic or sewage system, underground or on the surface, fuel storage, and the status of existing system(s)
- Location of land application or storage of pesticides, herbicides, and fungicides, inorganic fertilizers, road salt and nutrients
- Distance to and location of any nearby roads, intersections, parking areas
- Location of electrical lines or other potential overhead or underground utilities or hazards
- Location of any previous or existing wells and status – depth, abandoned, by whom, why, when, etc.
- Planned property uses including future grading of the ground surface
- Planned water uses
- Information about geology and formations, aquifer types likely present (i.e. location, rock type and fracturing of any bedrock outcrops on the property or adjacent properties) from well records, oil and gas records or area hydrogeological and geotechnical reports.
- Position of any features, structures and septic systems or other potential contamination sources on adjacent properties
- Position of wells on adjacent properties
- Accessibility issues to ensure the well is accessible for maintenance

Reminder: Well construction may require additional approvals (e.g. Permit to Take Water or environmental compliance approval for a flowing well discharging greater than 50,000 L/day). These approvals should be requested and obtained in advance of a well construction operation.

Reminder: See “Tools for Siting the Well” in this chapter for information and actions involved with site research and assessment.

Assessing and determining potential sources of contaminants is dealt with on a case by case basis. A source of contaminants list may include but is not limited to the following:

- All components of a sewage system under the *Building Code Act* or *Environmental Protection Act*,
- A farm animal feed lot,
- An animal manure pile,
- A barn and barnyard used for domestic animals,
- A lagoon,
- An underground or above ground storage tank and lines that are designed to hold and move petroleum hydrocarbons, volatile organic compounds, polychlorinated byphenyls, phenols and other organic chemicals,
- An open or closed hazardous or non hazardous landfill or dump,
- A sewer line,

- A pond,
- Fertilizers, pesticides, herbicides storage and other chemical storage areas,
- Liquid or solid waste transfer facilities,
- Sewage sludge and bio-solid waste spreading and irrigation sites, and
- Winter sand and salt storage facilities.

Reminder: For a more detailed description of “source of contaminant” and “contaminant” see Chapter 2: Definitions & Clarifications, Table 2-2.

How To Assess Contamination Flow

Contaminants, such as bacteria, hydrocarbons and chemicals, can move easily through soil and even more easily through fractured bedrock. Where fractured bedrock occurs at or near the land surface, the potential for contaminants to get into the groundwater is high.

When contaminants move through soil and fractured rock they generally follow the flow of the groundwater. Therefore, it is important to always take the groundwater flow pattern into consideration when siting a well.

Groundwater flow direction can be complex to determine, but the flow often follows the contour or slope of the land and typically discharges into surface water bodies. Figure 4-1 demonstrates potential risks and the flow of contaminants into and with groundwater.

Scenarios where groundwater flow may be complex include the following:

- Multiple shallow and deep aquifers are present and have different groundwater flow directions,
- Preferential flow pathways exist, such as buried hydro or gas lines,
- Many wells pump groundwater from a single aquifer, and
- Wells are present that pump large volumes of groundwater, at a high rate, from an aquifer.

In these and other complex scenarios, the flow of the groundwater is best determined by a Professional Engineer or Professional Geoscientist.

Figure 4-1: Risk of Contamination [2]

The figure is a cross section illustration of a farm on top of an aquifer system. The farm consists of, from left to right, a homestead with a septic field to the right of the house, followed by a berm with trees, a diesel storage tank, a barn, and a drive shed. There is a well to the left of the homestead, and a well to the right of the barn. The ground consists of, from top to bottom, an unsaturated zone, a vadose zone, an unconfined aquifer, a clay aquitard, a confined aquifer, and fractured bedrock. Groundwater is identified as flowing from left to right across the section.

The well to the left of the homestead is an open pipe well, with the pipe extending from above ground surface and into the confined aquifer. The water level in the well extends upwards into the clay aquitard, indicating that the confined aquifer is pressurized and therefore considered artesian. The well to the right of the barn is also an open pipe well, with the pipe extending from above ground surface and into the top of the unconfined aquifer. The water level in the well is at the same level as the surrounding aquifer .

There are four sources of contaminants illustrated to be entering or already in the aquifer system. The contaminants are identified by arrows in the unsaturated zones, by pools where free product exists, and by dots in the aquifer representing dissolved concentrations. The contaminants include:

1. The septic bed to the right of the homestead is discharging effluent downwards through the unsaturated and vadose zones, entering the unconfined aquifer. The contaminants then mix in the aquifer and flow to the right, passing the barn well. They contaminants in the aquifer are identified by green dots.
2. The diesel storage tank is discharging light non-aqueous phase liquid (LNAPL) through the unsaturated and vadose zones, and is pooling on top of the unconfined aquifer. Some of the LNAPL is dissolving in the unconfined aquifer and flowing to the right, towards the barn well. The LNAPL pool and dissolved dots are represented in purple.
3. Contamination is entering the ground between the barn and the barn well, discharging effluent downwards through the unsaturated and vadose zones, entering the unconfined aquifer. The contaminants then mix in the aquifer and flow to the right, passing the barn well. They contaminants in the aquifer are identified by green dots.
4. A dense non-aqueous phase liquid (DNAPL) is discharging from the drive shed, through the unsaturated and vadose zones, and is pooling at the bottom of the unconfined aquifer. The unconfined aquifer has a slight dip to the left (upgradient) and some of the DNAPL is flowing to the left, while dissolved DNAPL is also flowing right in the direction of groundwater flow. Some of the free-product DNAPL is moving down through the clay aquitard at the bottom of the unconfined aquifer and entering the confined aquifer, where it pools at the bottom on the aquifer. The LNAPL pool and dissolved dots are represented in red.

There are also green dots in the confined aquifer, which appear to represent contamination from either the septic bed or contamination from the barn.

Selecting The Site

After the potential sources of contamination and groundwater flow direction have been identified, the well must be sited using the minimum setback distances (see Plainly Stated in this chapter). In addition, the following best management practices are recommended to protect well water quality.

Best Management Practice – Siting the Well Upgradient of Sources of Contamination

Where possible, a well should be located up gradient of potential sources of contamination such as septic systems, storage tanks and others (see Chapter 2: Definitions and Clarifications, Table 2-2 "contaminant")

Best Management Practice – Exceed Minimum Setback Distance

In some situations it is important to exceed the minimum setback distance specified in the *Wells Regulation*. For example:

- Any time the natural features of the site indicate that contamination could travel easily and quickly to the water source, and
- If the well is going to be:
  - Situated in a shallow aquifer,
  - Set in highly fractured bedrock with thin soil, or
  - Located down gradient from a potential contamination source (remember to consider neighbouring properties)

Reminder: The *Wells Regulation* does not specify a minimum setback distance between a new well and a property line.

Best Management Practice – Recommended Setback Distances from Property Line

Where practical, it is recommended that at least a minimum (or an increased – see the Best Management Practice above) setback distance be applied from the well to all property lines because it is unlikely a well owner can control what happens on adjacent properties. The appropriate setback distance will be dependant on the type of well (e.g, deep drilled or shallow dug) and geologic conditions encountered.

Reminder – See "The Requirements – Plainly Stated" on this chapter for minimum separation distances.

Best Management Practice – Siting the Well in Complex Geology

Where complex geology exists or contamination is likely to be encountered, it is recommended that a Professional Engineer or Professional Geoscientist be retained to site the well.

Best Management Practice – Siting a New Well Near an Existing Water Supply Well

During the planning phase of a new well, all nearby wells should be identified and assessed to determine the impact that the planned well construction could have on the well. If it is determined there is a likelihood that the planned well construction operation may impair the water in a nearby well, drilling should not proceed or proper contingency plans should be put in place to protect the nearby water supply well.

Accessibility And Elevation

The *Wells Regulation* requires the person constructing a well to site a new well to be accessible for cleaning, treatment, repair, testing, inspection and visual examination at all times before, during and after completion of construction of the well and at a higher elevation than the immediate surrounding area.

The person constructing the well is responsible for ensuring that the new well will be accessible at all times, and taking steps identifying all existing and proposed structures and landscaping that may impact the accessibility. A new well is inaccessible when:

- A building (other than a pump house) or driveway is built over the top of the well
- Buildings or structures are constructed around the well preventing equipment, including a drilling rig or excavator, from accessing the well to rehabilitate, deepen or decommission the well
- The ground surface is landscaped in a manner that prevents equipment, including a drilling rig or excavator, from accessing the well to rehabilitate, deepen or decommission the well

Figure 4-2: Well Located Within A Building

This figure shows a well located within a building. The well is not accessible for significant repairs such as replacing the well casing. New wells in a building, such as a residence, are not allowed under the *Wells Regulation*.

Clarification of the Term Higher Elevation

For the purposes of constructing a new well on a higher elevation, a new well can be constructed on a sloped property.

However, the *Wells Regulation* does not allow a new well to be constructed where the ground surface immediately around the well slopes towards the well.

For example, the well cannot be constructed in a ditch.

Where To Record The Well Location

Once a site for the well has been selected, the location of the well must be carefully noted on the well record, including both the Universal Transverse Mercator (UTM) coordinates using a Global Positioning System (GPS) receiver, and an accurate site sketch.

The *Wells Regulation* requires that a GPS receiver be used to locate the well with accuracy. The UTM coordinates must be recorded as shown in Figure 4-3.

Frequently, well record location data is inaccurate, which limits the usefulness of the record. Providing the most accurate location information is extremely important because it helps to do the following:

- Identify and locate a well in case of a spill,
- Locate a well when maintenance is needed,
- Ensure the correct well is decommissioned in an area with multiple wells,
- Allow for well inspections when a property is being sold, and
- Determine and interpret local groundwater conditions in a given area.

Figure 4-3: Well Record - Recording Well Location

Well Location

- Address of Well Location (Street Number/Name)
- Township
- Concession
- County/District/Municipality
- City/Town/Village
- Province: Ontario
- Postal Code

- UTM Coordinate: NAD S3
    - Zone
    - Easting
    - Northing
- Municipal Plan and Sublot Number
- Other

Map of Well Location

- Please provide a map bellow following instructions on the back
- Well owner's instruction package delivered
    - Yes
    - No
- Date Package Delivered
- Date Work Completed

Reminder: To allow for the well in the field to be matched with the well record in the Ministry database, it is extremely important that the person constructing the well, fully and accurately completes the well record including all relevant location information. See Chapter 13: Well Records, Documentation, Reporting & Tagging for further guidance on filling out the well record.

Tools For Siting The Well

Site Research & Assessment

Table 4-3: Important Information and Actions for Researching and Assessing a Site

What information is Important?	Why is it important?	What actions should be taken?
Size and shape of the property.	• Know the boundaries.	• Look for an Ontario Land Survey or legal property survey (e.g, municipal office.) • Create a site plan or simple map based on observations and client's knowledge.
Position of any features, structures and septic systems or other potential contamination sources on adjacent properties.	• Contaminants in, on, or below ground do not stay in one location but have the potential to migrate.	• Walk around the property . • Talk to the neighbours. • Observe and add to site plan.
Planned property uses as potential sources of contamination.	• Anything the client is planning to do on the site may alter siting plans. Examples include future manure piles, fertilizer mixing areas and pesticide mixing areas.	• Discuss with the client. • Add to site plan.
Distance to and location of any nearby roads, intersections.	• Source of road salt and potential contaminants (e.g. oil spills from containers, fuels).	• Observe • Measure • Add to site plan

What information is Important?	Why is it important?	What actions should be taken?
Location or planned location of any structures, and their purpose.	• Barns, tractor shed; storage for pesticides, herbicides, and fungicides, inorganic fertilizers, fuel and road salt; repair shops, cattle pens and other structures where potential sources of contaminants will be located.	• Discuss with the client, builder, or construction manager. • Add to site plan.
Landscaping and final grade of site.	• To ensure proper drainage, height of the casing, accessibility and elevation of the well as specified in the *Wells Regulation*.	• Discuss with the client, builder, or construction manager. • Add to site plan.
Location or planned location of septic system, underground fuel storage system; and check status of any existing systems.	• To ensure compliance with separation distances specified in the *Wells Regulation* and Building Code. • Assess potential hazards on site (e.g, leaky or abandoned fuel storage system).	• Discuss with client. • Observe. • Add to site plan.
Information about the geology and the overlying soils.	• Aquifer types common to the area will help assess the potential for contaminants to travel. • Understand typical yields and natural water quality and expected well depth.	• See a copy of area formation maps and reports at local municipal, local Conservation Authorities (e.g, source protection planning maps), Ministry of the Environment and Climate Change, Ministry of Northern Development and Mines and Ministry of Natural Resources offices. • Review well records. • Add to site plan.
Topographical features.	• The slope or contours of the land help determine the direction of the groundwater flow.	• Observe the land and note all surface water, hills, valleys, cliffs, caves, etc. • Use topographical maps. • Add to site plan.
Location of previous or existing wells and status.	• Knowledge of existing and abandoned wells will assist in identifying special conditions such as flowing wells, poor water quality, low yield, natural gas, excessive depths, etc. • Unused and improperly abandoned wells may act as pathways for contamination and create hazards.	• Ask the client. • Walk the property. • Review well records. • Properly plug and seal any unused or improperly abandoned wells in accordance with the *Wells Regulation*. • Add to site plan.
Position of wells on adjacent properties.	• The pumping of one well may affect the performance of another. • Drilling of well may cause drill cuttings to impair well water in nearby wells. • Large production wells may have an impact on contaminant movement.	• Talk to the neighbours. • Observe. • Add to site plan. • If possible, seek permission to assess neighbour's well water for background purposes prior to starting to construct a new well.

What information is Important?	Why is it important?	What actions should be taken?
Planned water uses to assess potential water quantity needs.	• Large municipal taking will require a higher yield than a typical private residential well. • Certain demands will also increase the required yield, such as lawn watering or filling a swimming pool. • Understanding planned water uses allows for the estimation of water needs and minimum water quality.	• Discuss with the client. • Add to site plan.
Location of hydro lines or underground services/utilities.	• May be a threat to personal safety and equipment.	• Check with local utilities such as hydro, gas, cable, water, sewer and telephone (i.e. “Call before you dig”) and retain qualified person to locate. • Observe. • Discuss with client. • Add to site plan.
Accessibility.	• For well construction equipment access. • For cleaning, treatment, repair, testing, inspection and visual examination as required in the *Wells Regulation*. • For future well maintenance and abandonment (plugging and sealing) as required in the *Wells Regulation*.	• Observe. • Add to site plan.

5. Constructing, Casing and Covering the Well

Chapter Description

This chapter covers common well construction methods and materials used in Ontario. The minimum requirements for the hole, casing and well screen and advantages and disadvantages of wells constructed using different equipment and materials are also covered. This chapter is structured to parallel the steps involved in the construction of the hole, installation of the casing, creation of the annular space and, where used, installation of the well screen. The filling of sealant in the annular space is covered in Chapter 6: Annular Space & Sealing.

Regulatory Requirements - Hole & Casing

Relevant Sections - The Wells Regualtion

- Log & Field Notes – Section 12.1
- Covering of Well – Section 12.2
- Surface Drainage – Section 12.3
- Well Depth Requirements – Section 12.4
- Well Pits – Subsections 12(7), (7.1), (8) and (9)
- Casing – Section 13
- Deepening of Wells – Section 13.1
- Annular Space – Subsection 14.2(1), Subsection 14.2(2) paragraph 2, Subsection 14.3(1), Subsection 14.4(1), Subsection 14.4(2) paragraph 3, Subsection 14.4(3)
- Double Walled Casing – Section 14.6
- Information – Subsection 16(3)
- Abandonment – Subsection 21(7)

The Requirements - Plainly Stated

Reminder: Figure 5-23 to Figure 5-30 at the end of this chapter show many of the requirements listed in the Plainly Stated section

The *Wells Regulation* requires the following when a person constructs a water supply well, unless an exemption is provided in this section.

Log Book and Field Notes

The person constructing the well must have an on site, current and detailed:

- log of overburden and bedrock materials encountered when advancing the hole, and
- field notes regarding the construction of the well.

Exemptions - Log Book

The person constructing the well is required to keep up-to-date field notes but is not required to have a log of overburden and bedrock materials if the person is constructing the well by the use of a driven point (e.g., direct push technology, jetting).

Reminder: For further information on log books and field notes requirements and exemptions, see Chapter 13: Well Records, Documentation, Reporting & Tagging.

Covering the Well

Whenever the well is left unattended during construction, the person constructing the well must cover the upper open end of the well securely in order to prevent the entry of surface water and other foreign materials.

Minimum Depth of a New Well

If a new well is being constructed by any method, it must be at least 6 metres (19.7ft) deep unless the only useful aquifer is shallower.

In cases where the only useful aquifer is less than 6 metres (19.7 ft) deep, the well must be at least 3 metres (10 ft) deep.

Reminder: For clarification of the term useful aquifer see Chapter 2: Definitions & Clarifications, Table 2-2.

Well Casing and Well Screen Construction for a New Well

The casing and well screen for a new well must:

- be new materials,
- be clean and free of contamination, and
- not cause contamination of the water with which they are in contact.

Reminder: The requirement for a casing and well screen to be made of new materials prohibits the re-use of a casing or well screen that was previously installed in a finished well (i.e., where its structural stage has been completed). The requirement for a casing to be made of new materials does not apply to starter (working) casing.

Well Casing Sections for a New Well

The casing must be watertight.

Only continuous sections of casing (e.g., no holes or perforations or slots in the well casing) can be used in the construction of a new well.

The casing must meet the minimum standards as outlined in Table 5-1.

Well Casing Seams for a New Well

Any seams in the casing must be permanent and watertight.

Well Casing Joints for a New Well

Joints in casing are not allowed unless they:

- achieve a permanent, watertight bond, such as welded steel joints, and
- are made so that the jointed casing does not impair the quality of water with which it comes in contact.

Concrete Well Casing and Casing Joints for a New Well

If the casing is concrete:

- it must be fully cured and commercially manufactured,
- the concrete sections must be properly aligned so that the joints are flush and the casing is centred, and
- the sections must be joined with a mastic sealing material that remains pliable and waterproof and is approved for potable water use by NSF International.

Reminder: For clarification of the terms “permanent,” “watertight” and “waterproof” see Chapter 2: Definitions & Clarifications, Table 2-2.

Minimum Length of Well Casing Underground for a New Well

Where the useful aquifer is greater than 6 m (19.7ft) below the original ground surface, the casing for a new well must extend at least 6 m (19.7ft) below the original ground surface.

If the only useful aquifer is located between 3 m to 6 m ((10ft to 19.7ft) below the ground surface, the casing for a new well must extend at least 2.5 m (8.2ft) below the level of the original ground surface.

Reminder: For clarification of the terms “useful aquifer”, “permanent”, “watertight” and “waterproof” see Chapter 2: Definitions & Clarifications, Table 2-2.

Surface Drainage (Earth Mounding) around the Well

The person constructing the well must ensure that the slope of the ground surface (surface drainage) is such that water will not collect or pond near the well. Proper surface drainage can be ensured by properly mounding with earth around the well and outward from the well to direct surface drainage away from the well.

Extent of Casing for a New Well in an Overburden Aquifer

Unless exempt, a new well that obtains water from an overburden formation must be cased:

- from the water intake zone,
- to at least 40 cm (16 inches) above the highest point on the ground surface within 3 m (10ft) radially from the outside of the casing after the land is properly mounded for surface drainage as measured on completion of the well’s structural stage.

There is an exemption to this casing requirement which will be discussed in this “Plainly Stated” section (a well constructed by use of a driven point).

Reminder: For clarification of the term “well’s structural stage” see Chapter 2: Definitions & Clarifications, Table 2-2.

Extent of Casing for a New Wells in a Bedrock Aquifer

A new well that obtains water from a bedrock formation, must be cased:

- from the bedrock,
- to at least 40 cm (16 inches) above the highest point on the ground surface within 3 m (10ft) radially from the outside of the casing after the land is properly mounded for surface drainage as measured on completion of the well's structural stage.

There is an exemption to this casing requirement which will be discussed in this “Plainly Stated” section (a well constructed by use of a driven point).

Reminder: For clarification of the term “well’s structural stage” see Chapter 2: Definitions & Clarifications, Table 2-2.

Sealing Casing in Bedrock for New Drilled Wells

If the aquifer is located in a bedrock zone that is not weathered, the casing of a new drilled well, other than a test hole or dewatering well, must be sealed into the bedrock with suitable sealant to prevent impairment of the quality of the groundwater and the water in the well.

Reminder: For clarification of the term “weathered bedrock” see Chapter 2: Definitions & Clarifications, Table 2-2.

Casing Height Exemption for New Driven Point or Jetted Point Wells

An exemption to the minimum casing height requirement of 40 cm (16 inches) above the ground surface exists if the new well is made by the use of a jetted point or driven point and it has a visible, permanent marker.

In these cases, the casing must:

- extend a sufficient height to permit the attachment of a well tag, and
- be at least as high as the highest point on the ground surface within a 3 m (10ft) radius of the well’s casing for any new well after ground surface is properly mounded with earth to direct surface drainage away from the well as measured on completion of the well’s structural stage.

The permanent marker must also identify the location of the well and be visible at all times of the year.

Reminder: For additional information on casing height and surface drainage see Chapter 7: Completing the Well’s Structure.

Reminder: For clarification of the terms water intake zone and water producing zone see Chapter 2: Definitions and Clarifications, Table 2-2.

Casing Height and Mounding for a New Well in a New Well Pit

If a new drilled well is constructed with a new well pit, the top of the casing of the new drilled well must be at least 40 cm (16 inches) above the floor of the well pit.

The well pit must be cased from the bottom of the well pit to at least 40 cm (16 inches) above the highest point on the ground surface within 3 m (10ft) radially from the outside of the casing as measured upon completion of the well’s structural stage.

The ground surface around the new well pit must be properly mounded to prevent ponding near the well.

New Well Pit Construction for a Well

All new well pits are banned in Ontario, with the exception of:

- wells constructed by diamond drilling equipment that are used in connection with mineral exploration and
- test holes or dewatering wells completed with a properly constructed flush-mounted well pit (vault).

Lightning Rod attachments to Casing for New Wells

A lightning rod is not allowed to be attached, directly or indirectly, to the casing of a new well.

Deepening of an Existing Well

If the well is deepened, all of the casing requirements and exemptions apply, but the existing casing can continue to be used if it appears sound.

A well is not allowed to be constructed by penetrating through the bottom of a bored or dug well by:

- means of drilling,
- the use of a jetted point or
- the use of a driven point.

Information – Encountering Natural Gas

Where a well is constructed and natural gas is encountered, the person constructing the well must immediately notify the well purchaser, the owner of the land on which the well is situated and the Director that the condition exists.

Table 5-1: Minimum Casing Specifications for New Well Construction

Casing Type	Wall Thickness	Inside Diameter	Required Standards
Steel	• Nominal wall thickness of 4.78 mm (0.188 inches), and • Minimum wall thickness of 4.18 mm (0.16 inches)	≥ 50.8 mm (2.00 inches)	• ASTM A–53 Grade B, • ASTM A589 Grade B, or • ASTM A500 Grade B or C
Steel	• Nominal wall thickness of 2.77 mm (0.11 inches) and • Minimum wall thickness of 2.41 mm (0.09 inches)	≤ 50.8 mm (2.00 inches)	• ASTM A–53 Grade B, • ASTM A589 Grade B, or • ASTM A500 Grade B or C
Galvanized (bored and dug wells only)	18 gauge	No minimum diameter	Must be corrugated • ASTM A–53 Grade B, • ASTM A589 Grade B, or • ASTM A500 Grade B or C
Concrete	Nominal thickness of 5.08 cm (2.00 inches)	≥60.96 cm (24.00 inches)	No standard, but must be fully cured and commercially manufactured
Plastic (PVC or ABS)	Minimum thickness of 0.635 cm (0.25 inches)	≥10.16 cm (4.00 inches)	Must be PVC or ABS and approved for potable water use by ASTM or NSF International
Fibreglass	No minimum thickness specified	No minimum diameter	Must be manufactured from virgin resin and virgin fibres and must be approved for potable water use by NSF International
High Yield Wells	Minimum thickness dependent on type of material	Minimum diameter size dependent on type of material	Must follow the casing specifications in Table 2 of AWWA A100–06
Double Walled Casings	Minimum thickness dependent on type of material.	Minimum diameter size dependent on type of material	The outer permanent casing in double walled casing construction must be steel pipe that conforms to ASTM A252 or ASTM A500

Reminder: See Table 5-7 in this chapter for advantages and disadvantages of different types of well casing.

The *Wells Regulation* **does not allow** the use of certain materials as well casing for new well construction. Some examples include the following:

- Casing such as large diameter perforated corrugated pipe (culvert) not approved for potable water use,
- Plastic casing that is not approved for potable water use, and
- Hand lain stone, bricks, wood etc.

Reminder: See the section titled “Improper Casing for New Well Construction” in this chapter for photographs of unapproved types of well casing material.

Relevant Sections - Additional Regulations Or Legislation

Ontario Regulation 213/91 (Construction Projects) as amended made under the *Occupational Health and Safety Act*

Ontario Regulation 387/04 (Water Taking) as amended made under *Ontario Water Resources Act*

Relevant Standards

ASTM Standard ASTM A252, 98(2007). “Standard Specification for Welded and Seamless Steel Pipe Piles.” ASTM International, West Conshohocken, PA, 2007, DOI: 10.1520/A0252-98R07, ASTM website.

ASTM Standard A500/A500M, 2007. “Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes.” ASTM International, West Conshohocken, PA, 2007, DOI: 110.1520/A0500_A0500M-07, ASTM website.

ASTM Standard ASTM D5088, 02(2008) “Standard Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites” ASTM International, West Conshohocken, PA, 2007, DOI: 0.1520/D5088-02R08. ASTM website.

ASTM Standard D1173, 2007. “Standard Test Method for Foaming Properties of Surface-Active Agents.” ASTM International, West Conshohocken, PA, 2007, DOI: 10.1520/D1173-07. ASTM website.

ASTM Standard A589/A589M, 2006. “Standard Specification for Seamless and Welded Carbon Steel Water-Well Pipe.” ASTM International, West Conshohocken, PA, 2006, DOI: 10.1520/A0589_A0589M-06, ASTM website.

ASTM Standard F480, 2006b. “Standard Specification for Thermoplastic Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDR), SCH 40 and SCH 80.” ASTM International, West Conshohocken, PA, 2006, DOI: 10.1520/F0480-06B, ASTM website.

ASTM Standard C990M, 2006 (2009). “Specification for Joints for Concrete Pipe, Manholes, and Precast Box Sections Using Preformed Flexible Joint Sealants.” ASTM International, West Conshohocken, PA, 2009, DOI: 10.1520/C0990-09, ASTM website.

ASTM Standard ASTM C478-07 (2009). “Standard Specification for Precast Reinforced Concrete Manhole Sections.” ASTM International, West Conshohocken, PA, 2009, DOI: 10.1520/C0478-07, ASTM website.

NSF International Standard/American National Standard 61, 2008. “Water Treatment and Distribution Systems - Health Effects.”

NSF International, Ann Arbor, MI 2008. NSF website: Certified fibre-reinforced plastic casing for potable water use (see NSF Products and Service Listings).

American Water Works Association (AWWA). 2003. ANSI/AWWA C 654-03 “Disinfection of Wells.” AWWA, Denver, CO, 2003.

American Water Works Association (AWWA). 2006. ANSI/AWWA A100-06 “Minimum Requirements for Vertical Water Supply Wells.” AWWA, Denver, CO, 2006.

Well Record - Relevant Sections - Hole & Casing

The *Wells Regulation* - The graphic below shows a sample of the details to be completed on the well record when constructing the hole and installing the casing and well screen in the well.

Figure 5-1: Well Record - Relevant Sections

Well Use

- Public
- Domestic
- Livestock
- Irrigation
- Industrial
- Commercial
- Municipal
- Test Hole
- Cooling and Air Conditioning
- Not used
- Dewatering
- Monitoring
- Others; specify

Method of Construction

- Cable Tool
- Rotary (Conventional)
- Rotary (Reverse)
- Boring
- Air percussion
- Diamond
- Jetting
- Driving
- Monitoring

Hole Diameter

- Depth from (m or ft)
- Depth to (m or ft)
- Diameter (cm or in)

Construction Record - Casing

- Inside Diameter (cm or in)
- Open Hole or Material (Galvanized, Fibreglass, Concrete, Plastic, Steel)
- Wall thickness (cm or in)
- Depth from (m or ft)
- Depth to (m or ft)

Construction Record - Screen

- Outside Diameter (cm or in)
- Material (Galvanized, Fibreglass, Concrete, Plastic, Steel)
- Slot No.
- Depth from (m or ft)
- Depth to (m or ft)

Best Management Practice – Reporting Concrete Tile Screens

When constructing a well screen with unsealed concrete tiles, the concrete tiles should be recorded in the "Material" section of the "Construction Record – Screen" box of the well record.

Figure 5-2: Well Record-Relevant Sections(Continued)

Overburden and Bedrock Materials/Abandonment Sealing Record

The back of the well record provides instructions on how to record the details of this section. The example provided is for construction and is recorded in metric units:

- Coulour
  Record the colour of the formation from the list (white, grey, yellow, brown, blue, red, green or black)
- Material
  Record the material found in the formation (if more than one material exists, record the primary material in the first column and all others in the second column).
  Choose materials from the back of the well record (fill, mulch, peat, clay, silt, gravel, stones, boulders, top soil, fine sand, medium sand, coarse sand, limestone, dolomite, shale, sandstone, slate, quartzite, granite and greenstone).
- Depth
  The depth of each formation encountered must be recorded.
  All measurements must be recorded in the units indicated at the top of the well record
  All depth measurements are recorded as depth from the ground surface

Reminder: For additional information on filling out the well record see Chapter 13: Well Records, Documentation, Reporting & Tagging.

Key Concepts

Contructing the Hole

Prior to constructing the hole, the person constructing the well should research and assess the site and surrounding area using the tools outlined in Chapter 4: Siting the Well, Table 4-3: Important Information and Actions for Researching and Assessing a Site. Proper research and assessment covers the location of aquifers, nature of geological formations, sources of contaminants, the purpose of the well and site accessibility.

Successful completion of a well depends on the use of equipment and materials that are appropriate for the environmental conditions and geological formations encountered at a site. It is important to consider the characteristics of the drill rig or other well construction equipment including the cutting action and any flushing medium (i.e., drilling of fluid and its circulation path).

Casing

Definition - The *Wells Regulation* defines casing as “pipe, tubing or other material installed in a well to support its sides, but does not include a well screen.”

Well Screen

Definition - The *Wells Regulation* defines a well screen as perforated pipe or tubing, unsealed concrete tiles or other material installed in a well to filter out particulate matter, and form the water intake zone.

To prevent water bearing formation collapse into the well and reduce sediment or particles in the well water, a well screen should be installed in all unconsolidated formations, in most semi-consolidated formations and sometimes in bedrock.

Common Types of Well Construction

There are four main types of wells constructed in Ontario:

- Drilled
- Bored/Augered
- Dug (by hand or excavating equipment)
- Driven or jetted

Table 5-2, below provides general characteristics, advantages and disadvantages of the common types of wells.

Table 5-2: Common Types of Water Wells [1]

Well Type	Suitable Geologic Materials	Advantages	Disadvantages
Drilled Wells [Commonly 15.9 cm (6 inches) in diameter, up to 9,000 m (30,000 ft) deep]	• Overburden and Bedrock	• Drilling systems can reach greater depths than other techniques • Typically yields a consistent rate of groundwater during periods of low recharge • Can penetrate bedrock • Could be less subject to surface and near surface sources of contamination depending on the environment	• Small diameter well provides little storage capacity • May encounter deep groundwater with naturally occurring elevated minerals and gas

Well Type	Suitable Geologic Materials	Advantages	Disadvantages
Dug Wells [Commonly ≥ 1 m (3 ft) in diameter, up to 10 m (30 ft) deep]	• Overburden • Sometimes are blasted in bedrock and then area and hole are excavated using digging equipment	• Large diameter well typically provides storage reservoir • Does not require specialized equipment • Common backhoe or high hoe using hydraulic shovel can perform the work	• Water shortages can be more common during dry periods because of shallow depths • Susceptible to surface and near surface sources of contaminants • Labour intensive to construct and maintain • Well depth limited by excavating equipment
Bored Wells [Commonly ≥ 1 m (3 ft) in diameter, up to 30 m (100 ft) deep]	• Overburden	• Large diameter well typically provides storage reservoir	• Water shortages can be more common during dry periods because of shallow depths • Susceptible to surface and near surface sources of contaminants • Well depth limited by caving conditions
Driven-point or Jetted Driven Point wells [Commonly ≥ 5 cm in diameter]	• Overburden	• Can be done with hand held or small inexpensive drilling machines • Wells can be connected together to increase yield	• Water shortages can be more common during dry periods because of shallow depths • Susceptible to surface and near surface sources of contaminants • Small diameter well provides little storage capacity

What to Consider when Constructing a Water Supply Well

Persons constructing water supply wells should research, and be familiar with, the geologic formations in the areas where they construct the wells.

Geologic Formations

Geological materials encountered during well construction could include:

- overburden formations – such as clay, silt, sand, gravel, or stones
- bedrock formations – such as sandstone, limestone, granite, or other bedrock

Reminder: See Chapter 2: Definitions & Clarifications, Table 2-1, for definitions of “overburden” and “bedrock.”

Advancing holes require construction equipment and tools, cutting actions and flushing media appropriate to the geologic formations encountered in each specific hole.

Location Of The Aquifer

Well purchasers, with the assistance of their licensed well technicians or environmental consultants (i.e., Professional Engineers or Professional Geoscientists), can assess and review groundwater reports and well records near the area of the proposed well to understand the subsurface conditions and their implications prior to constructing the wells.

Contaminated Sites

If there is any known or suspected contamination at the site, it is important to consider the following questions:

- What decontamination procedures must be established from hole to hole?
- How are water and/or soil to be contained if contaminated?
- Where will contaminated water and/or soil be stored or disposed of?
- Who will handle the storage and disposal of contaminated water and/or soil?
- What additional health and safety precautions should be taken?
- What is the contingency plan for the rescue of any affected personnel, including identification and location of medical and emergency resources for the site?

Reminder: See Chapter 5: Siting Considerations & Initial Planning for further information on geologic formations, aquifer locations, contaminated sites and environmental site characterization

Accessibility or Space to Work on the Site

It is important that the proper authorization to access and enter the property and to do the work be obtained from the owner of the land and any other party that has an interest in the land (e.g., tenant).

Site access or space to work on the site is an important consideration. Overhead or underground utilities or obstructions may not allow certain equipment (e.g., a drilling rig) to be admitted. Small working space or long distances from roadways may also limit equipment access to the well site. In certain situations, separation distances from sources of contaminants should also be considered (e.g., establishing background groundwater quality).

Reminder: See Chapter 4: Siting the Well for further information on accessibility or space to work at the well site.

Purpose of the Water Supply Well

There are many reasons to construct a well. The purpose of the well may also dictate what type of equipment is required to construct the well. For example, a specialized rotary drilling rig may need to be used to construct a deep large diameter municipal well.

Reasons for constructing a well include the following:

- Domestic water supply
- Livestock watering
- Irrigation
- Industrial
- Commercial
- Municipal or communal water supply
- Public supply
- Cooling, air conditioning or heating (geothermal well)
- Dewatering
- Testing and monitoring
- Recharge (where well is located into groundwater or an aquifer)

Constructing Wells by Different Methods

The following sections provide the key considerations when constructing the hole. Figures 5-23 to 5-30 in the “Diagrams for Common Well Types” section, at the end of this chapter, further illustrate well construction considerations.

Choosing a Construction Method

The construction method:

- should be able to penetrate the geological formation,
- should allow the person constructing the well to get representative samples of geological formation material, to identify the boundaries of permeable zones,

- must allow for the proper recording of formations, including aquifers, encountered during construction,
- must not contaminate the groundwater or the environment,
- unless otherwise exempt, must meet the minimum depth and diameter requirements of the *Wells Regulation* (see Table 5-5 and Figures 5-23 to 5-30 for minimum diameters), and
- should be able to penetrate the geological formation.

Table 5-3 provides methods, characteristics, and some general advantages and disadvantages of various well construction systems in particular formations.

Table 5-3: Well Construction Systems [2] [3]

System	Characteristics	Advantages	Disadvantages
Conventional Rotary Drilling Water or Mud	• Hole Diameter: 7 to 120 cm (3 to 24 inches) • Depth: 0 to 9000 metres (0 to 30,000 ft) • Cutting action and bit consist of rotary crush/tri or bi cone • Continuous rotation of the drill stem (rod) with the bit or cone breaks the formation • Rotation speeds of the drill cone or bit vary from 15 to 750 rotations per minute • Drilling fluids are forced down the inside of the drill stem • Drill cuttings are removed by either water or mud drilling fluid • Rig: Table or top drive mud pump • Can drill in overburden and bedrock	• Penetration rates high • Minimal casing required to keep hole open during operation • Quick set up with rig • Well screens can be set easily as part of casing string • Filter pack and suitable sealant can be readily placed in the hole • Can drill a deep hole fairly quickly in overburden and bedrock	• Difficult to drill in boulders or cobbles • Rigs costly, high maintenance • Rig mobility limited to solid ground conditions • Not good in cold conditions • Drilling fluid management requires special skill • Drilling fluids (water or mud) can be lost or difficult to maintain in fractured bedrock • Drilling fluids can clog the formation • Completed well may be difficult to develop because of mud or filter-cake on wall of hole • Location of water bearing zones may be difficult to detect • Difficult to collect accurate samples to determine screen slot size
Conventional Rotary Drilling Air	• Hole Diameter: 7 to 75 cm (3 to 30 inches) • Depth: 0 to 1,500 metres (0 to 5,000 ft) • Cutting action and bit consist of rotary crush/cone and rotary cut/drag bit • Air, instead of a drilling fluid, is forced down the inside of drill stem and lifts groundwater and cuttings up and out of the well • Can drill in shallow overburden and bedrock but more commonly used in fractured bedrock environments	• Quick cutting removal • Good in cold weather • Penetration rates high • Drilling mud or water not required • Aquifer clean of flushing media • Relatively easy to identify the formation materials • Relatively easy to develop the well • Bit life extended • Can estimate yield during drilling	• Difficult to use in overburden environments • Rigs costly, high maintenance • Rig mobility limited to solid ground conditions • Air, cuttings, groundwater and possible contaminants blown from hole can be a hazard to crew and environment • Casing required to keep hole open in the overburden and broken bedrock

System	Characteristics	Advantages	Disadvantages
Reverse Circulation Rotary	• Hole Diameter: 60 to 125 cm (24 to 50 inches) • Depth: 0 to 1,500 metres (0 to 5,000 ft) • Cutting action and bit consist of rotary crush/tri or bi cone or rotary cut/drag bit • Drilling fluids are circulated down the hole outside of the drilling rods and pumped up through the inside of the drill bit and drill stem • Water is typically used as the drilling fluid • Rig: reverse circulation • Can drill in overburden and bedrock	• Similar advantages as Conventional Rotary Drilling with water or mud • Less drilling fluid additive is required to lift cuttings during drilling • Quick development time • Larger diameter holes can be drilled • Drilling fluid loss is minimal because drilling fluid is being pushed at a low velocity • Works well in many overburden and sedimentary bedrock formations	• Similar disadvantages as Conventional Rotary Drilling with water or mud • A large amount of water is needed to keep the hole open during drilling • Rigs costly, high maintenance • Extra costs for additional drill pipe being installed for deep wells • Rig mobility limited to solid ground conditions • Not good in cold conditions • Drilling fluid management requires special skill • Not suitable for metamorphic or igneous bedrock formations
Dual Wall Reverse Circulation Rotary	• Hole Diameter: 9 to 25 cm (3.5 to 10 inches) • Depth: 0 to 610 metres (0 to 2,000 ft) • Cutting action and bit consist of rotary crush or rotary percussion • Similar to reverse circulation rotary except an additional outer drill pipe is used • Fluids or air are circulated down between the inner and outer pipes and pumped up through the inside of the drill bit and drill stem • Can drill in overburden and bedrock	• Similar advantages as Conventional Rotary Drilling with water or mud or air depending on the application • Reduces lost circulation of drilling fluids	• Similar disadvantages as Conventional Rotary Drilling with water or mud or air depending on the application except for the loss of circulation of drilling fluids • Limited diameter and depth • Needs well trained crew
Dual Rotary/ Casing Advancement	• Hole Diameter: 7 to 120 cm (3 to 24 inches) • Depth: 0 to 400 metres (0 to 1,312 ft) • Cutting action and bit consist of rotary cut, rotary crush or rotary percussion • Casing string is rotated using a casing rotator and pulled downhole just behind drill string and bit or in some cases ahead of the bit • Drilling bit typically has an under-reamer, which allows the bit to swing out below the casing and retract into the casing when drilling is complete • Drilling fluids circulated similar to Conventional Rotary systems • Typically used in overburden and broken (weathered) bedrock	• Similar advantages as Conventional Rotary Drilling with water or mud or air depending on the application except good for most overburden environments • Reduces lost circulation of drilling fluids • Able to determine water flow at any time	• Similar disadvantages as Conventional Rotary Drilling with water or mud or air depending on the application except for the loss of circulation of drilling fluids • Relatively expensive • Requires larger set up area and support equipment

System	Characteristics	Advantages	Disadvantages
Down-the-Hole Hammer (Air Percussion Rotary)	• Diameter: 10 to 90 cm (4 to 36 inches) • Depth: 0 to 610 metres (0 to 2,000 ft) • Cutting action and bit consist of rotary percussion or button bit • The repeated motion (similar to a jack hammer) crushes the material at the bottom of the hole • Commonly used in bedrock	• Quick cutting removal • Aquifer clean of flushing media • Easier to identify the formation materials • Good in cold weather • Penetration rates high • Well development relatively easy	• Rigs costly • Limited to bedrock • Rigs heavy, limiting accessibility • May require lubrication of the bit during drilling • Can cause fracturing of hole
Cored Hole / Diamond Drilling	• Hole Diameter: 6 to 11 cm (2.5 to 4.5 inches) • Depth: 0 to 3,050 metres+ (0 to 10,000 ft+) • Cutting action and bit consist of rotary abrasive • Similar to Conventional Rotary Systems	• Portable • Will not fracture rock • Can use air as flushing medium • Can drill holes at angle	• Similar flushing method related disadvantages as Conventional Rotary Drilling with water or mud or air depending on the application • Slower than other rotary drilling methods • Cost per metre (foot) may be higher than other drilling methods • When using water as the drilling fluid (medium), a large volume of water is needed
Cable Tool	• Hole Diameter: 10 to 120 cm (4 to 48 inches) • Depth: 0 to 1,500 metres (0 to 5,000 ft) • Cutting action and bit consist of percussion, chisel bit or button bit • Repeated dropping of a heavy string of drill tools and a bit crushes material at the bottom of the hole • During drilling in overburden, casing is driven to keep the hole open • The cuttings are removed by a bailer. • Commonly used for shallow overburden formations from 0 to 45 metres (0 to 150 ft) • Commonly used in shallow limestone bedrock and other soft bedrock from 0 to 30 metres (0 to 100 ft)	• Can be used in bedrock and overburden • Can drill through boulders and highly cavernous or fractured rock • Rigs inexpensive, easy maintenance • Low energy needs • Good in cold weather • Hole stabilized during drilling using casing • Excellent method when lost circulation of drilling fluid is a problem • Excellent method for development of well • Typically a very good method to detect low yielding groundwater bearing zones	• Penetration rates slow • May be difficult to pull long strings of casing with a rig that does not have special equipment • Heavier wall, larger diameter casing than most other methods • Heavy steel drive pipe can limit accessibility • Temporary casing can impact placement of filter pack and sealant (grout) • Heaving of sediment into bottom of casing can be a problem

System	Characteristics	Advantages	Disadvantages
Bucket Auger	• Diameter: 60 to 120 cm (24 to 48 inches) • Depth: 0 to 40 metres (0 to 130 ft) • Cutting action and bit consist of rotary cut • Used in overburden only	• Fast method for constructing large diameter wells	• Limited to about 30 metres (100 ft) in depth • May be limited to formations that will not collapse • Cannot penetrate bedrock formations • Generates a large volume of soil to be removed
Excavator	• Diameter: 1 to 10 metres (3 to 30 ft) • Depth: 0 to 10 metres (0 to 30 ft) • Removal of material with hydraulic shovel • Used in overburden • Sometimes a space in the bedrock is blasted breaking the consolidated rock. The broken rock in the blasted area is excavated using digging equipment	• Fast method of constructing large diameter wells	• Limited to about 10 metres (30 ft) in depth • Cannot penetrate bedrock formations unless the designated space in the bedrock is blasted • Generates a large volume of excavated material to be removed • Creates an extremely large annular space requiring proper sealing when cased
Sonic	• Uses high frequency downward vibration with the addition of a hydraulically powered drill head that applies pressure to the drill stem (working/starter casing) • Hole Diameter: up to 30 cm (12 inches) • Depth: 0 to 213 m (0 to 700 ft) • Frequency of vibration 0 to 185 cycles per second	• Drilling in most unconsolidated and soft bedrock (e.g., limestone) formations is rapid. • Allows drilling string to advance quickly through difficult materials including cobbles, boulders and construction debris. • Continuous formation sampling is part of the drilling process and is not an additional cost. • Since the hole is cased to the bottom, well installation is efficient • Well development, water sampling, and pumping tests can be done rapidly because little or no drilling fluid is used	• Equipment is not readily available and costly. • Equipment is large and if it is mounted on a tandem or tri-axle vehicle it may create site access issues. • The vibratory action causes compaction of some formations and loosening of others. • Cannot be used in hard bedrock (e.g., granite) • Requires addition of drilling fluids for bedrock formations • Potential to damage well screens when starter casing is removed • Potential for smearing with clay or silt when starter casing is removed

System	Characteristics	Advantages	Disadvantages
Jetting	• Diameter: 5 to 10 cm (2.5 to 4 inches) • Depth: 0 to 10 metres (0 to 30 ft) • Removal of material by washing action of high pressured water • Casing and driven point (drive point) advance as the material is removed • Used in overburden only	• Equipment is very mobile and can access hard to reach sites • Fast method of constructing small diameter wells • Relatively inexpensive method	• Depth constraints: Limited to about 10 metres (30 ft) in depth • Cannot be used in bedrock, cobbles, boulders or well cemented formations • Hard to penetrate through gravel layers • Potential for soil compaction and smearing • Small diameter well may yield relatively low rates of water • Subject to caving where the casing is not installed at the time of jetting • Jetting action may create a significant annular space requiring proper sealing • A large volume of water is needed
Driving	• Diameter: 5 to 10 cm (2.5 to 4 inches) • Depth: 0 to 10 metres (0 to 30 ft) • Casing and driven point (drive point) are pushed into the ground using a tool bar or hammer • Used in overburden only	• Equipment is very mobile and can access hard to reach sites • Fast method of constructing small diameter wells • Has significantly lower cost than other methods (e.g., augering, drilling)	• Depth Constraints: Limited to about 10 metres (30 ft) in depth • Cannot be used in bedrock, cobbles, boulders or well cemented formations • Hard to penetrate through gravel layers • Potential for soil compaction and smearing • Small diameter well may yield relatively low rates of water • The use of couplings to join casing lengths could create a small annular space that will be difficult to seal

Table 5-4 provides some general information on the speed of the construction equipment, when used in a particular environment and formation, to construct different types of wells. The table does not provide a ranking.

Table 5-4: Formations And Some Appropriate Construction Equipment [4]
Rate of Penetration: 1=Impossible 2=Difficult 3=Slow 4=Medium 5=Rapid 6=Very Rapid

Type Of Formation	**Cable Tool**	**Dirtect Rotary (with fluids)**	**Dirtect Rotary (with air)**	**Down-the-hole-hammer**	**Drill-through-casing hammer**	**Reverse Rotary(with fluids)**	**Reverse Rotary(dual wall)**	**Hydraulic Perussion**	**Jetting**	**Driven****	**Auger**	**Digging**
Dune Sand	2	5	NR	NR	6	5*	6	5			3 or 4	5
Loose sand and gravel	2	5	NR	NR	6	5*	6	5	5	3	3 or 4	5
Quicksand & flowing sand	2	5	NR	NR	6	5*	6	5	5	n/a	1	***
Loose boulders in alluvial fans or glacial drift	3 or 2	2 or 1	NR	NR	5	2 or 1	4	1	1	NR	3	2
Clay and silt	3	5	NR	NR	5	5	5	3	3	n/a	3	3

Type Of Formation	Cable Tool	Dirtect Rotary (with fluids)	Dirtect Rotary (with air)	Down-the-hole-hammer	Drill-through-casing hammer	Reverse Rotary(with fluids)	Reverse Rotary(dual wall)	Hydraulic Perussion	Jetting	Driven**	Auger	Digging
Firm shale	5	5	NR	NR	5	5	5	3	n/a	n/a	n/a	n/a
Sticky shale	3	5	NR	NR	5	3	5	3	n/a	n/a	n/a	n/a
Brittle shale	5	5	NR	NR	5	5	5	3	n/a	n/a	n/a	n/a
Sandstone - poorly cemented	3	4	NR	NR	n/a	4	5	4	n/a	n/a	n/a	n/a
Sandstone - well cemented	3	3	5	NR	n/a	3	5	3	n/a	n/a	n/a	n/a
Chert nodules	5	3	3	NR	n/a	3	3	5	n/a	n/a	n/a	n/a
Limestone	5	5	5	6	n/a	3	3	5	n/a	n/a	n/a	n/a
Limestone with chert nodules	5	3	5	6	n/a	3	3	5	n/a	n/a	n/a	n/a
Limestone with small cracks or fractures	5	3	5	6	n/a	2	2	5	n/a	n/a	n/a	n/a
Limestone - cavernous	5	3 or 1	2	5	n/a	1	5	1	n/a	n/a	n/a	n/a
Dolomite	5	5	5	6	n/a	5	5	5	n/a	n/a	n/a	n/a
Basalts - thin layers in sedimentary rock	5	3	5	6	n/a	3	5	5	n/a	n/a	n/a	n/a
Basalts - think layers	3	3	4	5	n/a	3	4	3	n/a	n/a	n/a	n/a
Basalts - highly fractured(lost circulation zones)	3	1	3	3	n/a	1	4	1	n/a	n/a	n/a	n/a
Metamorphic rocks	3	3	5	5	n/a	3	4	3	n/a	n/a	n/a	n/a
Granite	3	3	5	5	n/a	3	4	3	n/a	n/a	n/a	n/a

NR - Not Rcommended
n/a - Not Applicable

* Assuming sufficient hydrostatic pressure is available to contain active sand (under high confining pressures).

** Driven means manual and mechanical assisted methods (hand held, electric or pneumatic rotary hammers).

*** Digging in quicksand and flowing sand is not recommended because the hole is not cases as it is advanced and the formation will likely slough.

Reminder: Take all possible precautions to ensure that any contaminated water, soil, vapours or airborne contaminants are contained during all phases of construction.

If groundwater is anticipated to discharge or is discharging from a well during construction at a volume of more than 50,000 litres (11,000 Imp gal) on any one day, a Permit To Take Water under the *Ontario Water Resources Act* may be required. More information on Permit To Take Water approvals can be found on the Ontario website.

Reminder: The person constructing the well should ensure that the groundwater, drill cuttings and other materials discharging from the well do not cause environmental impacts such as erosion, impairment of surface water courses and off-site flooding. The use of settling pits on the property may be needed to contain the materials and prevent the above problems. A sewage works environmental compliance approval under the *Ontario Water Resources Act* may be required if the person constructing the well discharges the water, drill cuttings or other material and the discharge capacity exceeds 10,000 litres per day. A guide to explain the sewage works process can be found on the Ontario website.

Flushing Methods

Drilling fluids (flushing media) are an important consideration when choosing a construction method. During certain well construction, drilling fluids will help to do the following:

- Lubricate the drill bit, string and bearings to prevent breakdowns,
- Clean and cool the bit to allow for continued long periods of drilling without having to replace the bit,
- Stabilize the hole by exerting enough pressure to prevent caving,
- Seal the hole wall to reduce fluid loss to the formation, and
- Lift well cuttings from the bottom of the hole to the surface to allow drilling to continue into the formation.

There are three main flushing methods:

- Fluid based [e.g., water; water and bentonite (clay additives); water and polymeric additives; and water, bentonite (clay additives), and polymeric additives]
- Air based (e.g., dry air; air and water mist; air with a film of water containing a foam, and air, foam; and film strengthening materials, such as polymers and bentonite)
- Dry or mechanical based (uses a mechanical action)

For additional information on flushing media (drilling fluids) see the following:

- Table 7: Advantages and Disadvantages of Flushing Methods for Drilling Monitoring Wells, from the Fleming College Continuing Education Course Manual: Monitoring Wells – Construction (for Ontario Well Technicians).
- Practical Handbook of Environmental Site Characterization and Ground-Water Monitoring, Second Edition, by David, M. Nielsen (editor), CRC/Taylor and Francis, Boca Raton, FL, 2005 [5] .
- Chapters 16, 17 and 18 of Construction, Dewatering and Groundwater Control – New Methods and Applications, Third Edition [6] , and
- Chapter 8: Drilling Fluids, from Groundwater and Wells, Third Edition. Johnson Screens/ a Weatherford Company. New Brighton, Minnesota.

Location of the Aquifer - Shallow or Deep

A shallow aquifer may make it more feasible to use a backhoe or a boring rig to construct a large diameter well. Aquifers located in bedrock formations require specialized equipment designed to deal with these formations.

The *Wells Regulation* requires that new wells be a minimum 6 m (19.7ft) in depth unless the only useful aquifer (i.e., a water–bearing formation that is capable of transmitting water in sufficient quantities to serve as a source of a water supply) necessitates a shallower well. In no case is the well allowed to be less than 3.0 m (10ft) deep.

As indicated in Chapter 4: Siting the Well, Table 4-3: Important Information and Actions for Researching and Assessing a Site, well purchasers with the assistance of their licensed well contractors or environmental consultants can assess and review groundwater reports and well records near the area of the proposed well to determine potential groundwater locations.

Reminder: See Chapter 2: Definitions & Clarifications, Table 2-2 for clarification of the term “useful aquifer”.

Size Of The Hole

During construction of a well, an annular space is created when the size of the hole in the ground is larger than the casing and well screen diameter.

A properly filled annular space around a casing will:

- isolate a discrete zone,
- prevent migration of surface water and other foreign materials into the well and aquifers,
- prevent migration of groundwater and/or contaminants between water bearing formations and subsurface formations,
- prevent migration of groundwater and/or contaminants between water bearing formations and the ground surface,

- prevent aquifer depressurization by stopping the upward migration of water along the casing, or
- prevent gas migration.

Where an annular space is created, the space must be large enough to ensure:

- filter pack (clean washed gravel and sand) can be placed beside a well screen, if applicable, and
- suitable sealant (grout) can fill and adhere around the entire outer well casing to prevent surface water, groundwater, natural gas and other foreign materials from migrating along the outside of the well casing.

Figures 5-23 to 5-30 at the end of this chapter show many of the requirements listed in Table 5-5.

Table 5-5 may not apply to situations where an inner casing is surrounded by a larger diameter permanent outer casing. For further information see the double walled casing requirements in the "Plainly Stated" section of Chapter 6: Annular Space & Sealing.

In the case of a water supply well constructed by use of a driven point that creates an annular space, see Chapter 6: Annular Space & Sealing, for annular space sealing considerations.

Table 5-5: Minimum Hole and Annular Space Requirements

	Bored Well with Concrete Casing ≥ 6 m Deep	**Bored Well with Concrete Casing ≤ 6 m (19.7 ft) Deep**	**Dug(or Excavated) Well Jetted Well or Wells Constructed by the Use of a Driven Point**	**Drilled Well or Any Other Well ≥6 m Deep That is not Listed on this Table**	**Drilled Well or Any Other Well ≤ 6 m (19.7 ft) Deep That is not List on this Table**
Minimum Depth of Annular Space below Ground Surface at the Diameter Specified in the Next Row	≥ 6 m (19.7 ft)*	Where no well screen is installed: • Bottom of well If well screen installed: • bottom of well screen, and • top of the well screen must not be closer to ground surface than 2.5 m (8.2 ft)**	No minimum	≥ 6 m (19.7 ft)*	Where no well screen is installed: • bottom of well If well screen installed: • bottom of well screen, and • top of the well screen must not be closer to ground surface than 2.5m (8.2 ft)**
Minimum Diameter of Hole Greater than Outer Casing Diameter to Create Annular Space	≥ 15.2 cm (6 inches) from the ground surface to ≥ 2.5 m (8.2 ft) below the ground surface	≥ 15.2 cm (6 inches) from the ground surface to ≥ 2.5 m (8.2 ft) below the ground surface	No minimum	≥ 7.6 cm (3 inches)	≥ 7.6 cm (3 inches)

	Bored Well with Concrete Casing ≥ 6 m Deep	Bored Well with Concrete Casing ≤ 6 m (19.7 ft) Deep	Dug(or Excavated) Well Jetted Well or Wells Constructed by the Use of a Driven Point	Drilled Well or Any Other Well ≥6 m Deep That is not Listed on this Table	Drilled Well or Any Other Well ≤ 6 m (19.7 ft) Deep That is not List on this Table
Minimum Diameter of Hole Greater than Outer Casing Diameter to Create Annular Space	≥ 7.6 cm (3 inches) from ≥ 2.5 m (8.2 ft) below the ground surface	≥ 7.6 cm (3 inches) from ≥ 2.5 m (8.2 ft) below the ground surface	No minimum	• If rotary drilling equipment is used and centralizers are attached to casing ≫ 6 m below the ground surface: ≥ 5.1 cm (2 inches) • If cable tool equipment is used and a breakaway guide is attached 2 m above the bottom of any casing: ≥ 5.1 cm (2 inches)	• If rotary drilling equipment is used and centralizers are attached to casing ≫ 6 m below the ground surface: ≥ 5.1 cm (2 inches) • If cable tool equipment is used and a breakaway guide is attached 2 m above the bottom of any casing: ≥ 5.1 cm (2 inches)

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* If any annular space is created below 6 m below the ground surface, it must be sealed as described in Chapter 7: Annular Space & Sealing.

** The requirement does not apply to situations where an inner casing is surrounded by a larger diameter permanent outer casing (see the text before Table 5-5 and exemptions in "Plainly Stated" section of this chapter).

Best Management Practice – Determining the Size of Hole

A person constructing a cased well should create a hole diameter of sufficient size that will allow for:

- filling materials (e.g., filter pack) to be placed in the annular space around and above a well screen (if present), and
- suitable sealant to be placed in the annular space around the casing and adhere to the casing and formation.

In most subsurface conditions a person constructing a well should create a water supply well that is at least 10 cm to 20 cm (4inches to 8 inches) larger than the outer diameter of the casing. The larger size of hole facilitates the proper placement of the suitable sealant and filling materials in the annular space using a tremie pipe.

Care should be taken in determining the size of the hole. The person constructing the hole should ensure that the hole is able to accommodate a casing of sufficient size to allow for the installation of necessary downhole equipment (e.g., pumps).

Reminder: The same minimum hole diameter and annular space requirements and exemptions apply whether the casing is cylindrical or not, See Table 5-5 for additional details. For additional information on annular space and sealing requirements, see Chapter 6: Annular Space & Sealing.

Best Management Practice – Size of the Well's Annular Space

A person constructing a water supply well should always apply the minimum specifications in Table 5-5, the "Determining the Size of the Hole" BMP above and the Optimum Artificial Filter Pack Characteristics" BMP in the Artificial Filter Packs section of this Chapter, regardless of the length of time that a well is scheduled to be in operation

Contructing Straight and Plumb Holes

No single drilling construction method is best for every type of drilled well or every geologic condition. Each situation may call for a change in the cutting action, flushing media and equipment, as the construction progresses.

A crucial part of constructing a good vertical hole is ensuring that the hole is straight and plumb to minimize problems with placing the casing, placing filling material or suitable sealant in the annular space around the entire well screen and casing and installing pumping equipment.

Causes of a Crooked Hole

Some of the more common reasons that a hole is not straight include the following:

- Excessive pull down on drill string.
- Drilling aggressively through changing hard and soft formations.
- Deflecting off boulders.
- Collaring hole on sloping bedrock surface.

Figure 5-3: A Crooked Hole As A Result Of Drilling Tools Deflecting Off Boulders [7]

Reminder: During construction, a common practice is to use a mirror to reflect sunlight down the hole to permit a visual check on the straightness of the hole. The mirror observation method can be used to check for straightness if a plumb–bob is lowered down the hole. Specifically, a mirror can be used above the water level or when the well is dry to check the following:

- straightness of the hole,
- water levels,
- water entry points in cascading conditions or during pumping,
- condition of the hole or casing,
- occurrence of obstructions in the hole such as boulders, and
- occurrence of leakage of water and unconsolidated material at bedrock – casing interface.

The person constructing the well using rotary drilling equipment should use a mirror and watch the drill string when drilling and tripping in/out to see if the drill string stays in the centre of the casing in the collar area. If the drill string does not stay in the centre of the casing, the hole is not plumb and straight. If using this method, the person constructing the well should ensure that:

- the rig is stable and level, and
- a new or well maintained drill string is used to minimize the degree of deviation within the string.

Similarly, the person constructing well using cable tool drilling equipment should look at the relationship of the drill cable to the top of the casing. If the cable is always centred in the casing, then the hole is plumb and straight. If the cable is not centred, then the hole is not plumb and straight.

Best Management Practice – Use Stabilizers and Good Construction Techniques

To help minimize the occurrence of crooked or out of plumb holes, good construction techniques should be used in combination with stabilizers on the drilling tools and inclinometers to measure the angle of the holes.

Figure 5-4: A Drill Bit Stabilizer

Figure 5-4 shows a drill bit stabilizer. The circled portion shows the stabilizer has three ribs attached to the rod. The use of a stabilizer such as the one shown here, will help keep the hole straight by maintaining wall contact over a long distance.

Creation of Unintended Cavities, Voids and Spaces Outside of the Hole Area

Several factors can contribute to the creation of a cavity, void or space during well construction. These include:

- Cutting action
- Drilling system
- Flushing medium

- Local geology
- Casing accessories such as drive shoes, casing welds, weld rings and couplings
- Drill cuttings being pushed out of the hole

Best Management Practice – Reducing the Risk of Creating Spaces and Voids

To reduce the risk of unintended small voids and spaces that may be difficult to seal, the person constructing the drilled well should:

- Not use a drive shoe with a larger outside diameter than the casing (Table 5-9).
- Minimize the thickness of multiple pass welds (Table 5-9).
- Avoid using a weld ring as it can create a larger annular space (Table 5-9). Instead, a thicker walled casing [e.g., 6.4 mm (0.250 inches) – Table 5-9] should be used to increase the surface area at the ends of the casing to be welded. As an alternative, the person constructing the well should corner cut the casing ends at a 45 degree angle (beveled). The thicker casing provides a stronger welded joint without causing a larger annular space (Table 5-9).
- Minimize the use of band and coupled casing. Welded casing sections should be used instead.
- Use minimum volumes of air or water based flushing media with good drilling practices to minimize hole erosion and to avoid losing circulation.

For a well constructed by the use of a driven point, the person constructing the well should verify that the widest part of the driven point matches the outside diameter of the casing or screen. A wider point could create a very small annular space that is difficult to seal.

If any voids are created on the outside of the casing as a result of the drilling activity, the voids must be filled with suitable sealant or filling material as described in Chapter 6: Annular Space & Sealing.

Covering the Holes

An open hole or excavation is not only a safety hazard for children, farm animals and other living things it is also an open and direct pathway into the aquifer or other subsurface formation. An open well can allow contaminants from spills near the well to enter into the open hole and impair the aquifer.

The *Wells Regulation* requires that whenever a well under construction is left unattended, including during a minor alteration or the installation of a pump, the person constructing the well must cover the upper open end of the well securely in a manner sufficient to prevent the entry of surface water and other foreign materials into the well.

The person constructing the well must also ensure that the surface drainage is such that water will not collect or pond in the vicinity of the well.

Temporary covers need to prevent surface water or other foreign materials from entering the hole and be secure enough to prevent physical hazards and vandalism. Covering a well may include installing a lockable watertight well cap on top of the well and sealing the cover to the well casing. In cases where there is no casing in the hole, a temporary vertical tube and horizontal cover that is larger than the hole may need to be driven into the ground and around the well.

A person constructing a well must also use covers that meet the requirements of *Ontario's Construction Projects Regulation* (*Ontario Regulation 213/91* [8] made under the *Occupational Health and Safety Act*) to prevent physical accidents at the well site for the public and workers. The person constructing the well must also take other reasonable steps to secure the site. As such, leaving the drill rods and other tools in the hole, a piece of plywood lying on top of the well or putting a rag inside the well is not considered a proper well cover.

Recording Geological Information

The *Wells Regulation* requires that the person constructing a new well make a log of the overburden and bedrock materials (geological formations) and keep up-to-date field notes at the well site. This requirement also applies if the person is deepening the well.

A well that is constructed by the use of a driven point are exempt from the requirement to make and keep a log of overburden and bedrock materials but field notes are required to be made, kept up to date, and be available at the well site.

Reminder: See Chapter 13: Well Record, Documentation, Reporting & Tagging for further information on log book and field notes, and an example of a log book entry sheet.

Table 5-6: Particle Sizes for Overburden Materials [9]

Major Divisions	Subdivisions	Field Identification	Other Properties
Coarse-Grained Soils/ Sediments	Gravel	Particle size: 6 to 75 mm (¼ to 3 inches)	• Easiest to distinguish due to familiarity • Most important property to watch for is grade (well or poor)
Coarse-Grained Soils/ Sediments	Sand	Particle size: ≤ 6 mm (¼ inch), but large enough to be visible to the naked eye	• Easiest to distinguish due to familiarity • Most important property to watch for is grade (well or poor)
Fine-Grained Soils / Sediments	Silt	• Particle size: .002 to .08 mm (approximately 1⁄1,000 inch) • Powders easily when dry • Gritty to the teeth • Dries rapidly • No shine when moist and stroked with a knife blade	• Consist of particles of fresh-ground rock that have not had time to change their character into the minerals that make up clays • Can be easily recognized when water is present
Fine-Grained Soils / Sediments	Clay	• Particle size: ≤ .002 mm (1⁄1,000 inch) • Sticks to fingers when moist and does not wash off readily • Not gritty to the teeth • When moist, shiny surface is exposed when stroked with a knife blade	• Soils that are made up of the finest particles • Contain “clay minerals” which result from changes in the bedrock material through weathering

Reminder: Table 5-6 provides information on one of several grain-size scales used. This is one of several grain-size scales used. A grain-size scale widely used and accepted by geologists, the Udden-Wentworth grain-size scale, is described in Sedimentary Rocks in the Field [10] It divides sediments into seven grades: clay, silt, sand, granules, pebbles, cobbles and boulders and subdivides sands into five classes and silts into four.

The person constructing the well should collect representative samples at measured depths and at intervals that will show the complete geological character of the hole. For example, formation samples could be collected at 1.5 metre (5 inches) intervals and at every change in formation materials. The field notes should document the:

- change in formation materials including the top and bottom of each material/unit encountered,
- observed characteristics of each formation unit,
- depth to groundwater, water quality, natural gas and any other observations (e.g,, staining, sheen, odour),
- materials and equipment used at the site and in the well, and
- location information.

Reminder: See Chapter 13: Well Record, Documentation, Reporting & Tagging for further information on log books and field notes and for an example of a log book entry sheet.

Encountering Gas, Contamination and Water Quailty Problems

The *Wells Regulation* requires that the person constructing the well notify the well purchaser, the owner of the land on which the well is located and the Director if natural gas is encountered.

Definition - Natural gas or other gas is a gas produced from a well that has the potential to create conditions for explosions, poisoning, fire, asphyxiation or other adverse effects at the well site, within the water distribution system connected to the well or within buildings connected to wells. Some problematic gases that have been found in wells in Ontario include methane, hydrogen sulphide, propane, butane, benzene, carbon dioxide and other hydrocarbon based gases.

It is important to be prepared for site-specific conditions, which may include soil and groundwater contamination. Indications of contamination include:

- discolouration or milky colour of the water
- air bubbles in the water
- sheens on the water
- soil staining
- unexpected or foul smell
- hissing or degassing sounds

Best Management Practice – Using Gas Detection Equipment

There is a variety of direct reading instruments used for gas detection including the following:

- combustible gas indicators to measure the risk of fire and explosion, and
- oxygen deficiency meters to assess the level of oxygen in the air.

It is important that the person constructing the well be familiar with:

- gas detection equipment and its limited use and operation, and
- the geology and types of naturally occurring gases that may be encountered in the area.

This information may be available from well records and existing hydrogeological reports.

The person constructing the well should use the gas detection equipment during any well construction in case gas is encountered.

In some cases gas may accumulate in wells after construction. In areas prone to have natural gas, the person constructing the well should use gas detection equipment at least one week after the well has been constructed as a precautionary measure. Also, any person sampling or performing work on a well in areas prone to have natural gas should use gas detection equipment.

Best Management Practice – Encountering Unexpected Contamination or Gas

If unexpected contamination or gas is encountered in the construction (including alteration) of the well, the person constructing the well should stop work immediately to reduce serious dangers to the site crew, well owner and the environment.

To meet the obligation of reporting natural gas to the Director, the person constructing the well should contact the Ministry of the Environment and Climate Change through the Ministry's Spills Action Centre (SAC) at . The SAC is available to take calls 24 hours a day, 365 days a year.

Unexpected contamination that is encountered should be reported to the Ministry of the Environment and Climate Change local district office and well owner.

The Ministry can offer assistance and notify other agencies to help reduce serious dangers to the site crew, well owner and the environment.

Best Management Practice – Constructing the Hole in Areas Prone to Explosive Gases

To minimize the risk of gas causing an explosion or fire, a drilling system that uses a water-based drilling fluid and other equipment may be needed to temporarily contain and control the gas during well construction (see the 'Safety Considerations When Working on Contaminated Sites' section in this chapter for further information). As each environment is different, the person constructing the well should seek additional advice from a Professional Geoscientist or Professional Engineer on the gas issue before starting or proceeding further with the construction of the well. The Professional Geoscientist or Professional Engineer should create a work plan for the person constructing the well that:

- identifies equipment and procedures to be used to monitor for the presence and migration of hazardous gas;
- identifies measures to be taken to prevent or reduce the likelihood of the migration of hazardous gas,

- identifies measures to be taken to prevent or reduce the likelihood of the migration of hazardous gas,
- identifies a standard of protection that is at least equal to what is required in similar circumstances by “Oil, Gas and Salt Resources of Ontario - Provincial Operating Standards”, version 2.0, dated January 24, 2002 and published by the Ministry of Natural Resources, as amended from time to time, and
- includes a health and safety plan

Reminder: See Chapter 13: Well Records, Documentation, Reporting & Tagging for further information on reporting natural gas or contamination.

Casing

Definition - The *Wells Regulation* defines casing as pipe, tubing or other material installed in a well to support its sides, but does not include a well screen.

Casing acts to stabilize the hole, prevents unconsolidated overburden materials from entering the well water column, accommodates the pumping, or other equipment, and may be used to seal off or isolate unwanted formations.

The *Wells Regulation* requires that casings in new wells:

- be made of new materials,
- must not impair the quality of the water,
- must be watertight. Any casing joints and seams must be permanent and also watertight,
- must be clean and free of contamination (including the removal of all visible debris and material prior to the installation of the casing in the hole).

The *Wells Regulation* - In addition, any casing joints and seams must be permanent and watertight. Any materials used to join casing must not impair the quality of the water.

Best Management Practice – Cleaning Casing

Casing and equipment can be disinfected by following the instructions found in the American Water Well Association Standard C654 titled Disinfection of Wells [11] .

Additional information on disinfection of equipment can be found in Chapter 8: Well Disinfection, in the “Initial Steps for New Wells” section.

The *Wells Regulation* - Where the useful aquifer is greater than 6 m (19.7 ft) below the original ground surface, the casing for a new well must extend at least 6 m (19.7 ft) below the original ground surface.

If the only useful aquifer is located between 3 m to 6 m (10 ft to 19.7ft) below the ground surface, the casing for a new well must extend at least 2.5 m (8.2 ft) below the level of the original ground surface.

Reminder: For clarification of the terms “useful aquifer”, “permanent”, “watertight” and “waterproof” see Chapter 2: Definitions & Clarifications, Table 2-2.

Seating and Sealing Casing into Bedrock

The *Wells Regulation* - The person constructing a new well must properly seal the casing into the bedrock with suitable sealant to prevent overburden and other foreign materials from migrating under the casing into the well and potentially impairing the quality of the groundwater and water in the well.

Examples of properly sealing the well casing to the bedrock include:

- Seating the bottom of the well casing with a drive shoe into competent bedrock below the top of the overburden/bedrock interface.
- Placing bentonite or a cement product that is suitable for the environment in the annular space at the overburden/bedrock interface.

- A combination of seating the bottom of the well casing and placing a bentonite or cement product in the annular space at the overburden/bedrock interface.

Best Management Practice – Ensuring the Casing is Sealed in the Bedrock

To ensure that the casing is properly sealed into the bedrock, the person constructing the well should use one or both of the following methods:

- Downhole video camera for visual confirmation, or
- Hydraulic packer testing (i.e., sealing the well with an inflatable packer immediately below the well casing and filling the well column above the packer with water. If the water level or pressure in the casing drops then the bottom of the casing is not sealed).

Casing Materials

Choosing the casing material that is best for the specific situation includes consideration of the:

- physical strength to withstand the stress and weight of the formation with depth and seasonal changes such as freezing and thawing,
- resistance to the chemical composition of the groundwater and formation,
- formation characteristics,
- production capacity of the aquifer,
- potential contamination (chemical or biological) in the groundwater,
- purpose for the well, including water uses planned for the well, and
- size of the hole.

The *Wells Regulation* sets minimum specification standards including wall thicknesses for different types of casing materials in new wells including steel, concrete, fibreglass, and plastic. The casing standards are shown in Table 5-1 in this chapter and the descriptions with advantages and disadvantages are shown in Table 5-7.

Table 5-7: Advantages and Disadvantages of Different Types of Well Casing

Casing Materials	Characteristics	Advantages	Disadvantages

Casing Materials	Characteristics	Advantages	Disadvantages
Steel	Typically used in drilled wells. Reminder: Wall thickness requirements and relevant standards in Table 5-1: Minimum Casing Specifications for New Well Construction	• Very strong, durable, rigid • Less temperature sensitive than PVC, PTFE or fibreglass • Less expensive than stainless steel • Commercially manufactured well screens available	• Is subject to oxidation (rusts) • May react with metals • May be subject to corrosion (e.g., bi-metallic, pitting, stress) in environments that have: ◦ elevated hydrogen sulphide, ◦ low pH, ◦ high dossolved oxygen content, ◦ total dissolved solids ≥ 1,000 mg/L, ◦ carbon dioxide ≥ 50 mg/L, and ◦ combined chloride, bromide and fluoride ≥ 500 mg/L • Requires skilled welder to join casing sections together unless the sections are threaded
Stainless Steel	Typically used in drilled wells and in highly corrosive environments so that the life of the well is increased. Reminder: Wall thickness requirements and relevant standards in Table 5-1: Minimum Casing Specifications for New Well Construction.	• Less subject to corrosion than steel • Does not rust • Non-reactive to most chemicals • Very strong, so may be used in clay installations • Less temperature sensitive than fibreglass • Commercially manufactured well screens available	• Relatively expensive • Heavy to transport and work with • May react with metals • May be subject to corrosion when exposed to the following over a long term: ◦ iron bacteria or other microorganisms, and ◦ low pH or other geochemical conditions (see Steel above) • Requires skilled welder to join casing sections together unless the sections are threaded

Casing Materials	Characteristics	Advantages	Disadvantages
Concrete	• Typically used in bored and dug wells • Must be fully cured and commercially manufactured • Typically manufactured precast tile that has been reinforced • Tiles must be joined using mastic sealant that remains pliable, is waterproof, is approved for potable water use by NSF International and installed following manufacturer's recommendations Reminder: Wall thickness requirements in Table 5-1: Minimum Casing Specifications for New Well Construction.	• Stable • Properly designed manufactured precast tile provides good compressive strength • Readily available	• Prone to cracking • Subject to heaving • Heavy to move • Difficult to make permanent watertight joints
Thermal plastic - PVC	• Built to a physical standard that gives all sizes of pipe of the same collapse resistance within a strength standard • Must be approved for potable water use Reminder: The *Wells Regulation* does not permit the use of large diameter corrugated plastic pipe that is not approved for potable water use as casing for a new well. Reminder: Wall thickness requirements and relevant standards in Table 5-1: Minimum Casing Specifications for New Well Construction.	• Corrosion resistant • High abrasion resistance • Does not leach • Strong in most enviroments • Flexible • Light weight to transport and work with • Takes threads well • Inexpensive • Centralizers available to centre the casing in the hole • Commercially manufactured well screens available	• May fail under high pressure • May fail under high temperatures (e.g., during cement grouting of annular space) • May degrade when exposed to ultraviolet rays • Not suitable as riser pipe that is driven into the ground for driven wells
ABS (Plastic)	• Built to a physical standard that gives all sizes of pipe of the same collapse resistance within a strength standard • Must be approved for potable water use Reminder: Wall thickness requirements and relevant standards in Table 5-1: Minimum Casing Specifications for New Well Construction.	• Same advantages as PVC but better impact strength, better heat resistance and lighter weight	• Same disadvantages as PVC

Casing Materials	Characteristics	Advantages	Disadvantages
Fibreglass	• Must be manufactured from virgin resin and fibres • Must be approved by the NSF International for potable water use [12] • Casing needs to withstand tons of pressure exerted by the natural ground, especially with depth • Joined by male and female joint "spigot," screws and epoxy. The epoxy must not impair the quality of the water with which it comes in contact Reminder: Wall thickness requirements in Table 5-1: Minimum Casing Specifications for New Well Construction.	• Higher strength to weight ratio than galvanized casing • Resists corrosion	• Off the shelf fibreglass casings may not be used in certain conditions – see the best management practice following this table
Galvanized Steel	• Typically it is made up of wound/spiral casing and the seams must be welded to make the casing watertight • Strength comes from corrugated shape • Galvanized steel casing is made by electroplating the steel with zinc • There has been some concern that use of galvanized steel pipe can be the source of metals in well water such as lead or arsenic. The MOECC is not aware of arsenic hazards with galvanized steel in well water. To minimize the risk of heavy metal exposure and to meet the *Wells Regulation* requirement of not impairing the well water quality, it is important that electroplated casing using zinc with low levels of lead and other impurities be chosen. Currently the Ministry and World Health Organization [13] guidelines indicate galvanized steel casing does not create a well water health related concern and is an acceptable casing depending on the environment and well design Reminder: Wall thickness requirements and relevant standards in Table 5-1: Minimum Casing Specifications for New Well Construction.	• Can be strong depending on the environment	• Susceptible to corrosion • Requires skilled welder to join casing sections and seams together • Should not be used in corrosive water environments since the protective coating will eventually disappear and cause the casing to rust and deteriorate

Best Management Practice – Proper Use of Large Diameter Fibreglass Casing

It is the responsibility of the well technician to ensure that larger diameter fibreglass casing typically used in a dug and bored well is appropriate for the geologic environment and well depth. It is important that persons constructing large diameter wells consult with the manufacturers who make fibreglass casing for wells. To reduce the risk of well casing collapse, the fibreglass manufacturer should recommend a casing design for the installation. It is important that the person constructing the well then follow the manufacturer's recommendations.

Best Management Practice – Proper Use of Concrete Casing

The person constructing the well with concrete casing should consider using concrete tiles designed to ASTM C478–07 titled Standard Specification for Precast Reinforced Concrete Manhole Sections [14] .

The structure of the concrete tiles should be sufficient to prevent well collapse.

Concrete tiles should be carefully and evenly backfilled on the outside to ensure the tiles remain plumb.

Joining Casing Lengths

Well Casing Joints for New Wells

The *Wells Regulation* - Joints in casing are not allowed, unless the joints:

- achieve a permanent, watertight bond, such as welded steel joints, and
- are made so that the jointed casing does not impair the quality of water with which it comes in contact.

Joints for Concrete Casing in New Wells:

The *Wells Regulation* - If the casing is concrete:

- it must be fully cured and commercially manufactured,
- the concrete sections must be properly aligned so the joints are flush and the casing is centred and plumb, and
- the sections must be joined with a mastic sealing material (typically butyl rubber material) that remains pliable and waterproof and is approved for potable water use by NSF International Standard - NSF 61.

After the casing length has been attached, additional sand/cement mortar mixes could also be placed on the outside of the casing joint area to help seal the joint.

Best Management Practice – Proper Joining of Concrete Casing

All concrete tile joints should be designed to ASTM C990–06 titled Standard Specification for Joints for Concrete Pipe, Manholes, and Precast Box Sections Using Preformed Flexible Joint Sealants [15] .

Reminder: For unsealed joints in concrete tiles used as well screens see the section “Well Screens using Large Diameter Concrete Tiles,” of this chapter.

Table 5-8 provides suggestions and photographs for achieving watertight joints.

Even though Table 5-8 provides suggestions for joining casing, a person constructing a well should determine the type of bond used to seal the joint, or if the casing should even have joints, depending on the well design, environmental conditions and formation.

Reminder: Follow the manufacturer’s specifications regarding how to create permanent watertight joints between casing sections. Table 5-8 provides some suggestions for achieving permanent watertight joints.

Table 5-8: Suggestions for Achieving Permanent Watertight Joints

Casing Type	Method for Achieving Permanent Watertight Joints	Graphic
Steel Casing	Types of joints: • threaded flush-joint • plain • square-end or • bell-end When welding, use appropriate welding rod for creating the casing joints	• Steel Casing - Welded Using Three Passes • Steel Casing - Threaded

Casing Type	Method for Achieving Permanent Watertight Joints	Graphic
Concrete	Typically joined using bell and spigot method (see fibreglass casing type below). Use mastic sealant (typically butyl rubber material) that is approved for potable water use by the NSF International Standard 61. Concrete tile joints should be designed and sealed to ASTM C990–06 titled Standard Specification for Joints for Concrete Pipe, Manholes, and Precast Box Sections Using Preformed =Flexible Joint Sealants [16] .	• Roll of Mastic Sealant • Mastic Sealant Placed on Concrete Tile Joint – Open • Two Tiles Sealed Together with Mastic Sealant
Plastic	Types of joints: • flush-joint, threaded flush-joint, plain, square-end, or bell-end For PVC, use O ring on male thread as per ASTM Standard F480–06be1 "Specification for Thermoplastic Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDR), Schedule 40 and Schedule 80" [17] or tapered thread seals on shoulders or PVC primer and glue that is approved for potable water use by the NSF International For ABS use ABS primer and glue that is approved for potable water use by the NSF International. See best management practice following this table.	• PVC and Solvent Cement (must not impair the quality of the water with which it comes in contact). • PVC O-ring (no solvents used) • PVC Threaded (no solvents used)
Fibreglass	Joined by male and female joint "bell and spigot". The casing sections are attached with screws and also sealed with an epoxy. The epoxy must be a material that does not impair the quality of the well water	

Best Management Practice – Joining Sections of PVC Casing

When joining sections of PVC casing, follow ASTM Standard Specification for Thermoplastic Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDR), Schedule 40 and Schedule 80, ASTM Standard F480, ASTM, West Conshohocken, PA, 2004u.

Table 5-9: Plastic Casing Joining Method – Advantages and Disadvantages

Type	Method	Advantages	Disadvantages

Type	Method	Advantages	Disadvantages
Threaded Connections – Acme, Buttress, standard pipe, and square threads	• Sections are joined together by twisting. Wrapping the threads with fluoropolymer tape prior to joining sections improves the watertightness of the joint. • Because all joints in a well casing must be watertight, it is important that the extent to which the joints are tightened comply with recommendations of the manufacturer. • Where the annular space is minimal, threaded or other couplings should not be used to attach well screens to casing or lengths of casing together. Casings that do not use couplings are best suited for use in well construction.	• Casing with threads machined or moulded directly onto the pipe (without use of larger-diameter couplings) provides a flush joint between both inner and outer diameters. • Joints create a uniform inner and outer casing diameter in well installations.	• As most manufacturers have their own thread type, threaded casing may not be compatible between manufacturers. If the threads do not match and a joint is made, the joint can fail or leak either during or after casing installation. This could result in the following problems: • Inconsistent diameters between the well screen and casing and between casing lengths causes problems when tight-fitting downhole equipment (development tools, sampling or purging devices, etc.) is used. • An uneven outer diameter creates problems with filter pack and annular seal placement. Problems with the annular seal placement tends to promote water migration at the casing/seal interface to a greater degree than is experienced with uniform outer diameter casing.

Table 5-10: Metallic Casing Joining Methods – Advantages and Disadvantages

Type	Method	Advantages	Disadvantages
Welding Via Application of Heat	• Casing can either be butt welded or welded using a weld ring. In either case, three passes are made (see image in Table 5-8) • It is important that the person welding be aware of proper welding techniques and welding safety.	• May produce joints that are stronger than the casing and enhance the tensile strength of casing string.	• Greater assembly time. • Costly plastic welding equipment is required. • Difficulty in properly welding casing in the vertical position • Increased corrosion potential in the vicinity of the weld. • Danger of ignition of potentially explosive gases that may be present
Threaded Joints	• Sections are joined together by twisting. Wrapping the threads with fluoropolymer tape prior to joining sections improves the watertightness of the joint	• Inexpensive, fast and convenient connections • Greatly reduce potential problems due to corrosion. • Eliminate the risk of explosion as no welding is required.	• Tensile strength at the threaded joint of the casing string is reduced to approximately 70% of the casing strength. This reduction in strength typically poses a problem for larger diameter wells.

Improper Casing for New Well Construction

There are some commonly used casing materials that are not allowed for new well construction. Some examples of improper casing include large diameter perforated corrugated pipe (culvert) that is not approved for potable water use; plastic casing that is not approved for potable water use; hand lain stone, bricks or wood. Figures 5-5 to 5-12 provide examples of improper casing used in wells.

Figure 5-5: Interior of a Well with Plastic Corrugated Pipe

Figure 5-5 shows the interior of a well with plastic corrugated culvert pipes used as casing to support the new well's sides. Note the two pieces of corrugated pipe separated to allow waterlines and a cloth material into the well.

Figure 5-6 Perforated Hole in Plastic Corrugated Pipe

Figure 5-6 shows a pen placed in a perforated hole in the plastic casing. The separated casings and perforated openings allow for foreign materials and contaminants to enter the well. Plastic corrugated pipe is also not approved for potable water use and thus, there is a potential for the piping itself to impair the well water.

Figure 5-7: Installing Not Approved Galvanized Casing

Figure 5-7 shows a person installing galvanized steel casing into a well. However, the spiraling seam in the galvanized casing (typical of a cardboard tube holding a roll of paper towel or holiday paper) has not been welded. The seam is not watertight and allows for foreign materials and contaminants to enter into the well. In addition, the individual is not employing proper safety procedures when working within the excavation of the well.

Figure 5-8: Plastic Casing - Type Not Approved

Figure 5-8 shows plastic casing extending out of the top of drilled wells. The plastic pipe is not approved for potable water use and thus, there is a potential for the piping itself to impair well water. If the plastic pipe is approved casing, it will have labeling that identifies the pipe as approved for potable water use. Also, the plastic pipe has been attached improperly to steel casing by a clamping device. The attachment has a space that is not watertight and can allow for surface water and other foreign materials to enter the well and impair the well water.

Figure 5-9: Plastic Casing - Type Not Approved

Figure 5-9 shows another photograph similar to Figure 5-8 of plastic casing extending out of the top of drilled wells. The plastic pipe is not approved for potable water use and thus, there is a potential for the piping itself to impair well water. If the plastic pipe is approved casing, it will have labeling that identifies the pipe as approved for potable water use. Also, as in Figure 5-9, the plastic pipe has been attached improperly to steel casing by a clamping device. The attachment has a space that is not watertight and can allow for surface water and other foreign materials to enter the well and impair the well water.

Figure 5-10: Hand Lain Stone Used As Casing - Not Approved

Figure 5-10 shows hand lain stone used as casing. The openings between the stones allow for foreign materials and contaminants to enter into the well. The stone work may also not be structurally adequate to prevent collapse of the well over time. Also, the well cover consists of open wooden pallets that can allow surface water and other foreign materials a route of access into the well leading to the impairment of the well water.

Figure 5-11: Well Within Animal Feedlot - Non-Compliant

In Figure 5-11 the well is the building with the pitched roof on the left side of the photograph. The rectangular structure is located within an animal feedlot area. The well was used as a source of drinking water for human consumption. See Figure 5-12 for a discussion of the unapproved casing.

Figure 5-12: Inside the Well Within Animal Feedlot - Unapproved Casing

Figure 5-12 shows the interior of the well (building in Figure 5-11). This photograph shows that the well water is a very dark grey colour. Foreign material is floating on the well water. The sides of the well are supported by green painted wooden signs and wood poles. A waterline is extending out of the well water towards the top of the photograph and white styrofoam insulation lies over the well water. The wood used as casing allows for foreign materials and contaminants from the feedlot to enter into the well and impair the well water.

Casing Accessories

Table 5-11 provides details on the most common casing accessories.

Table 5-11: Casing Accessories

Casing Accessory	Characteristics	Graphics

Drive Shoes	• Protects the bottom of the casing from damage when pushing the casing into the ground and helps to seat the casing in bedrock formations
	• Types of drive shoes:
	  ◦ rotary or cable tool – Can be welded or threaded on in heavy duty or standard pattern, and
	  ◦ special application types include dual rotary shoe and eccentric shoe
	• Considered to be casing under the *Wells Regulation* definition
		Cable Tool Drive Shoe
		
		Rotary Drive Shoe

Weld Rings	• Increases the surface of the weld to make it stronger • Facilitates the welding of casing extensions in well pits • Relatively expensive • Considered to be casing under *Wells Regulation* definition • Must ensure minimum annular space is based on the widest part of the weld ring	
Casing Centralizers	• Used to center casing in hole to ensure even placement of grout around casing and formation stabilizer around the well screen	
Breakaway Guide	• A device that aids in proper alignment of the casing when using a cable tool rig by centering the casing. It must not impair the quality of the water with which it comes into contact • The breakaway guide is placed 2 m (6.5ft) from the bottom of the leading casing during installation	
Shale Trap	• Placed above screen assembly in annular space to prevent grout from entering the formation and well screen • Can be used to isolate or seal off poor quality groundwater zones above the well screen or water intake zone	
K-Packer Device	• Consists of rubber rings installed around a casing • Used to isolate or seal off poor quality groundwater zones	
Examples of casing for drilled wells with different wall thicknesses	• If not known, the wall thickness can be determined by calculating the difference between the outer diameter and the inner diameter divided by 2 • The casings to the right are marked with their wall thickness	

Casing Installation Techniques

Casing is installed using one of two techniques:

1. Forcing – the forcing techniques include driving, jacking, pushing and rotation.
2. Lowering – into an over sized hole.

Safety Note: Extreme care must be used when handling a long string of casing. In deep wells (e.g., 200 m) this is a significant concern for lighter casing materials (e.g., PVC) as well. Devices that require tension alone to hold and secure casing, such as slings and chains, should not be used. Instead, it is advisable to use proper casing elevators.

Centering the Casing

During installation, it is important to ensure casing is centred and vertically plumb in the well.

Proper centering and alignment of the casing in a vertically plumb hole will create an appropriately sized annular space that is consistent around the entire well casing. An appropriately sized annular space allows for even placement of filter pack materials and sealant (grout) around the casing.

Best Management Practice – Centering the Casing

For centering casing in drilled wells, it is important to use and properly attach centralizer devices (see Table 5-11, above) to the outside of the casing. It is important that centralizer devices are made of material that will not impair the quality of the water.

General Guidance for Using the Breakaway Guide:

A breakaway guide (Figure 5-13) may be used to centre the casing in a well constructed by a cable tool drilling rig. The use of a breakaway guide will allow the person constructing the well with a cable tool rig to create a smaller diameter annular space (minimum of 5.1 cm greater than the outer diameter of the casing versus a minimum of 7.6 cm) for a well.

Reminder: For additional information on minimum hole size and annular space requirements see Table 5-5 in this chapter.

When using these breakaway guides, the person constructing the well should:

1. Install the working (also called starter or surface) casing as plumb as possible into the hole. The working casing should be used to collar the hole and create a hole that is at least 5.1 cm (2 inches) or greater than the outside diameter of the permanent casing
2. Ensure that the drill string is centred in the hole.
3. Place the breakaway centralizer guide over the first section of permanent casing so that it is 2 m (6.6 ft) above the bottom of the first permanent casing.
4. Install the permanent casing into the well. The breakaway guide is held by cable hooks that rest on the top of the working casing.
5. If required, hold the permanent casing at the top with a casing elevator. Drilling the open hole out the bottom of the first permanent casing should continue until the open hole begins to collapse [e.g., 1 to 3 m (3.3 to 6.6 ft)].
6. Weld a second length of casing to the first permanent casing.
7. Pull out the breakaway centralizer guide using the cables and hooks.
8. Fill the annular space with suitable sealant (see Chapter 7: Annular Space & Sealing).
9. Continue drilling and advancing casing sections while keeping the sealant (grout) column in the annular space topped up to ground surface during well construction.
10. Pull the working casing and top up sealant (grout) to the ground surface when the well is finished.

Figure 5-13 shows a cross-section diagram of this process. The diagram uses the example of a well that is greater than 6 m deep and has a hole diameter (created by the outside diameter of a working casing) slightly greater than the minimum requirement of 5.1 cm larger than the finished permanent casing.

Reminder: All figures and diagrams are for illustrative purposes only and do not necessarily represent full compliance with other requirements found in the *Wells Regulation*.

Figure 5-13: Example Of The Use Of A Breakaway Centralizer Guide

Figure 5-13 shows a cross-sectional diagram of the installation of a breakaway centralizer guide in a drilled well. Figure 5-13 shows three steps.

The first step (Step 1) is shown on the left side of the diagram. Step 1 shows a vertical hole that extends 6 metres (19.7 feet) into the subsurface. A starter casing with an inside diameter of 23 centimeters (9.1 inches), extending from above the ground surface to 6 metres (19.7 feet) below ground has been placed in the hole. Within the starter casing, is a permanent inner casing with an inside diameter of 17 centimetres (6.7 inches). The permanent inner casing extends from above the ground surface to 6 metres (19.7 feet) into the subsurface. A breakaway guide is attached to the outside of the permanent inner casing and extends to the side of the starter casing. The breakaway guide is located about 2 metres (6.5 feet) above the bottom of the permanent inner casing. Hooks are attached to the top of the starter casing. Two cables extend from the hooks to the breakaway guide.

The second step (Step 2) is shown in the centre of the diagram. Step 2 shows a vertical hole extending 7 to 10 metres (23 to 32.8 feet) into the subsurface. A starter casing with an inside diameter of 23 centimeters (9.1 inches), extending from above the ground surface to 6 metres (19.7 feet) below ground has been placed in the hole. Within the starter casing, there is a permanent inner casing with an inside diameter of 17 centimetres (6.7 inches) which extends from above the ground surface to 6 metres (19.7 feet) into the subsurface. The permanent inner casing is comprised of two sections welded together. The joint between the second and first length of permanent inner

casing is located above the ground surfaceA breakaway guide is shown attached to the outside of the permanent inner casing and extends to the side of the starter casing. The breakaway guide has been raised from its location in Step 1 to just below the ground surface. Hooks are attached to the top of the starter casing. Two cables extend from the hooks to the breakaway guide. An open hole has been drilled 1 to 3 metres (3.3 to 9.8 metres) below the bottom of the casing.

The third step (Step 3) is shown on the right side of the diagram. Step 3 shows a vertical hole extending greater than 10 metres (32.8 feet) into the subsurface. A starter (or working) casing with an inside diameter of 23 centimetres (9.1 inches) has been placed in the vertical hole. The starter casing extends from above the ground surface to 6 metres (19.7 feet) into the hole in the subsurface. Two sections of permanent inner casing with an inside diameter of 17 centimetres (6.7 inches) are located within the starter casing. The permanent inner casing extends from above the ground surface to the bottom of the hole in the subsurface. The joint between the second and first sections of permanent inner casing is shown below the ground surface. The joint between the two permanent inner casing sections has been welded. The breakaway guide has been removed from the well. The annular space between the permanent inner casing and the starter casing has been filled with a suitable sealant.

- The first weld must be able to pass through casing centralizer guide.
- The casing in step 2 is held in place by the use of an elevator
- The starter, or working, casing must be removed before the structural stage of the well is complete.
- The outer diameter of starter or working casing maskes the hole diameter at least 5.1 cm (2 inches) greater than the permanent casing.

Reminder: The diagram above is not to scale and is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with the requirements found in the *Wells Regulation*.

Well Screens

To prevent water bearing formation collapse into the well and significantly reduce sediment or particles in the well water, it is important to install a well screen in all unconsolidated formations, in most semi-consolidated formations and sometimes in bedrock.

Definitions - The *Wells Regulation* defines a well screen as perforated pipe or tubing, unsealed concrete tiles or other material installed in a well to filter out particulate matter and form the water intake zone.

The *Wells Regulation* requires that well screens for new wells must be made of new materials that are clean and contaminant free. The well screen materials must not impair the quality of the water.

Best Management Practice – Cleaning Well Screens

Well screens, filter packs and equipment should be disinfected by following the instructions found in the most recent version of the American Water Works Association Standard C654 titled Disinfection of Wells.

Well screens that are permitted for use in wells are as follows:

- Commercially manufactured well screens
- Casings that are slotted or perforated to create well screens
- Concrete casings with unsealed joints to create well screens (see “Best Management Practice – Groundwater Entering Large Diameter Wells Cased with Concrete Tiles” on this chapter).

Best Management Practice – Using Clean Pre-Packaged Well Screens

A clean, commercially manufactured pre-packaged well screen that is designed for the formation where the screen will be placed, should be purchased and installed to prevent unconsolidated fines from entering the well and thus creating a hydraulically efficient well.

Reminder: To prevent casing and formation collapse, the person constructing the well should contact the manufacturer of casing before creating a well screen by perforating or slotting the casing.

Well Screen Design Considerations For Drilled Wells

Well Screen Slots, Length and Diameter

Well screen openings (or slots), screen length, and diameter are all selected to allow water to pass through a screen with the least friction, keep out aquifer formation material, and serve as a structural support for the well. Figure 5-14 shows a sample of a telescopic well screen. Telescopic well screens are designed to be pushed out the bottom of the casing. Other well screens are attached to the bottom of the first length of the casing.

Manufactured well screens are made of many materials including steel or plastic. The slots in the well screens may be designed as continuous, louvered, bridged, milled (vertical) and slotted plastic. Table 9.15 on page 398 of Groundwater and Wells: Third Edition [18] provides open areas of the different screen slots.

Under certain circumstances and when properly installed, plastic well screens provide wells with adequate structural strength, good hydraulic characteristics, and long life. To prevent the impairment of the well water and aquifer as required by the *Wells Regulation*, it is important that plastic well screens be approved for potable water use. To ensure sufficient structural strength, the screen manufacturer should be contacted for recommended wall thicknesses when plastic well screens are used.

Manufactured continuous-slot screens have larger open areas compared to the other types of screens. Smaller openings reduce yield, increase drawdown and make well development difficult. Continuous-slot openings are also V-shaped in design. The V-shaped opening allows the open area to widen into the screen. This slot design reduces clogging from elongated or oversized particles.

To ensure optimum use, the well screen entrance velocity needs to be calculated to prevent friction loss and increased rates of encrustation and corrosion.

Best Management Practice - Recommended Maximum Entrance Velocity for Well Screens

It is important that the screen should have a maximum entrance velocity that does not exceed 0.03 metres per second (or 0.1 foot per second) to reduce friction loss and rates of encrustation and corrosion.

The size of the screen slots is determined based on an analysis of the aquifer formation materials. The screen slot size is matched to the grain size distribution of the aquifer formation.

The function of the slot size is important in the well screen. Small openings limit well yield while large openings may not prevent the fine material from entering the well. As a general rule, the slots are sized as shown below in the criteria for selecting a well screen for a drilled well. Then, the formation is developed around the well screen to remove the fines through the screen, leaving the coarser material around the outside of the well screen slots.

Criteria for selecting a well screen for a drilled well include:

- Large percentage of open area
- Generally, where the uniformity coefficient(see definition below) is:
  - $\geq$ 6, the slot size needs to retain no less than 50% of the formation material
  - 3 to 6, the slot size needs to retain no less than 60% of the formation material
  - $\leq$ 3, the slot size needs to retain between 70% and 90% of the formation material
- Length of screen
- Planned yield of the well
- Non-clogging slots
- Resistance to corrosion
- Sufficient column and collapse strength
- Ease of well development
- Low potential for encrustation in the formation
- Low head loss through the screen
- Prevention formation collapse during development and when pumping the well

Reminder: Uniformity coefficient is the ratio of the sieve size that retains 40% of the formation material (passes 60% = D_{60}) to the sieve size that retains 90% (passes 10% = effective size) [19] .

The *Wells Regulation* - In cases where a new well with a well screen is constructed by a method other than digging or by the use of a driven or jetted point, the annular space shall be filled with clean, washed gravel or sand:

- from the bottom of the well screen to at least the top of the well screen, and
- not closer than six metres to the ground surface, unless the only useful aquifer available necessitates a shallower well, in which case the top of the gravel or sand shall not be closer than 2.5 metres to the ground surface.

The depth requirement for the top of the sand and gravel layer does not apply if the well is constructed with a casing surrounded by a larger permanent outer casing (sometimes referred to as a double walled casing).

Reminder: The depth requirement for the top of the sand and gravel layer also does not apply to wells constructed by digging or by the use of a driven or jetted point.

Reminder: See Chapter 6: Annular Space & Sealing for further information on requirements for a casing surrounded by a permanent outer casing.

Best Management Practice – Determining Well Screen Slot Size, Length and Target Depth for Wells

Care should be taken to choose the appropriate well screen slot size and length. Care should also be taken to place the well screen at the correct depth. The proper well screen characteristics and depth will allow the well to fulfill its intended purpose.

For example, when formation materials change with depth and the well is naturally developed, the screen slot size may need to be varied over the length of the well screen to match the grain size of the different formation materials.

Best Management Practice – Designing a Well Screen for Drilled Wells to Achieve a Sand-free State

To ensure the well screen chosen will not collapse and will prevent sediment from entering the well water, which could impact the pump operation and water quality, the person constructing the well should:

- only select a well screen that is commercially manufactured,
- ensure that the manufacturer of the well screen being used specializes in overburden grain size analysis, screen slot size and screen design,
- provide manufacturers with well depth and samples of the formation to be screened, or the results of a proper grain sieve analysis,
- determine if an artificial filter pack is necessary to increase well efficiency and to decrease sediment entering the well, and
- make the appropriate selection of manufactured screen material, opening, length and diameter with the assistance of the manufacturer.

Riser Pipes, Leading (Or Lead) Pipes, K-Packers and Plugs for Telescopic Well Screens

A typical manufactured telescopic well screen assembly (shown in Figure 5-14) is installed through the casing of a drilled well. It will consist of the following three following sections:

1. A properly sealed plug is located at the bottom of the well screen to prevent formation material from entering through the large opening at the bottom of the well screen. The plug is sealed by either being threaded in or by pressure fitted onto the bottom well screen. The plug should be made of a material (e.g., iron) that can be drilled out of the well for well rehabilitation and abandonment reasons.
2. The plug is sealed to a slotted section that has a precisely selected slot size and length.
3. A riser pipe is attached above the slotted section of the well screen. The top of the riser pipe is located close to the bottom of the well casing.

A K-packer (shown in Figure 5-14 and Table 5-11) is a commercially manufactured fitting that creates a watertight and sand-tight seal between the riser pipe and well casing. K-packers are commonly made of neoprene rubber, EPDM rubber or rubber and steel. In the past, packers were made of lead (Pb). However, well screen material, including the K-packer, cannot impair the quality of water with which it comes in contact. As lead (Pb) is a contaminant that can leach into the well water, lead (Pb) packers can no longer be used in well construction.

Best Management Practice – Packer Devices for Telescopic Well Screens

Persons installing well screens should use multiple (two or more) K-packers to eliminate the problems created by variations in casing or packer dimensions.

During installation, rubber rings (gaskets) of the K-packer can become damaged by contact with weld slags or beads within casing joints. To reduce damage to the K-packer, a non-toxic (i.e., food grade) lubricant that will not impair groundwater quality should be applied to the neoprene. The person constructing the well should always follow recommendations from the manufacturer regarding the use and installation of K-packers.

A short section of lead or leading pipe [e.g., 1 m (3ft) long] can be added to the bottom of the well screen assembly to create a sump. The term "lead pipe" is not the metal element Pb, but rather a pipe, typically made of stainless steel, that is leading or ahead of the well screen in the hole.

Best Management Practice – Using Bottom Caps or End Plugs

Bottom caps or end plugs should be used on all casing and well screen assemblies. Joints, caps and end plugs must be watertight and may be secured by welds, threads or force fittings. Solvents, glues or adhesives must not be used for casing or screen assemblies where they may impair the quality of the water (see the "Joining Casing Lengths" section of this chapter).

Figure 5-14: Manufactured Telescopic Well Screen Sample for Drilled Wells

Figure 5-14 shows a sample telescopic screen with multiple slot sizes (from coarse to finest). A typical well screen for domestic use in well construction does not have multiple slot sizes on a small length of screen.

Figure 5-15: An Example of a Telescopic Well Screen Assembly

Figure 5-15 shows a cross-sectional diagram of a telescopic well screen assembly. The diagram shows a hole extending vertically into the subsurface. A casing extends from above the ground surface into the hole. An annular space is located between the outside of the casing to the side of the hole. A well screen is shown within the bottom of the casing and extends out of the bottom of the casing into the bottom of the hole in the subsurface. The well screen is made up of a K packer, riser pipe, screen, coupling and plug. The K-packer is located at the top of the well screen and seals the inner casing and to the outside of the well screen. The riser pipe extends from the K-packer to below the bottom of the casing in the subsurface. The screen is located below the riser pipe in the subsurface. The coupling and plug are located below the screen.

Reminder: The diagram above is not to scale and is for illustrative purposes for this chapter only and does not necessarily represent full compliance with other requirements found in the *Wells Regulation*.

Filter Packs Around Well Screens for Drilled Wells

Filter packs are well sorted gravels or coarse sands that can be:

- developed around the well screen (naturally developed from native granular material),
- selected and placed into the hole surrounding the well screen and developed (artificial filter pack), or
- pre-packed between two manufactured well screens (called pre-packed well screens) and developed.

This packed zone separates the well screen from the natural aquifer material to prevent finer materials from entering the well and increases the effective well diameter. Where possible, the filter pack should extend a sufficient distance above the top of the screen to allow for settling during development.

Reminder: Unless exempt, the person constructing a new well must place filter pack in the annular space around the well screen and casing to the requirements found in the "Plainly Stated" section, Table 6-1A and Table 6-1B of Chapter 6: Annular Space & Sealing.

When selecting a well screen, a slot size should be chosen that will retain approximately 90% of the natural filter pack material after development (see the "Well Screen Slots, Lengths and Diameter," section of this chapter). The use of a filter pack will generally allow for a coarser well screen slot size. Coarser slot sizes can increase the well efficiency.

Artificial Filter Packs

There are circumstances where an artificial filter pack is preferred over a naturally developed filter pack. Two examples follow:

- Well screens with small screen slots are used with formations having uniform fine grained material. Small slot sizes can create low well efficiency and could reduce the chance of obtaining the desired yield.
- Open hole wells in semi-consolidated bedrock formations can have significant quantities of granular material released off the hole wall. The granular material can enter the water distribution system damaging the pumping equipment and impairing the water quality.

Persons constructing wells can remove formation material around a well screen and replace it with a relatively thin zone of coarse material to increase the well's efficiency, increase hydraulic diameter and prevent granular material from entering the well. The coarse material that is placed around the well screen is called an artificial filter pack.

As an alternative to placing coarse material around the well screen, the person constructing the well can install a manufactured pre-packed well screen.

The *Wells Regulation* requires artificial filter pack material or material in a pre-packed well screen to be clean, washed gravel or sand. The gravel or sand must be placed during or after placement of the well screen and casing.

The following best management practices (including Table 5-12) provide artificial filter pack characteristics for obtaining optimum well yield and information on placing artificial filter packs.

Best Management Practice – Optimum Artificial Filter Pack Characteristics

Table 5-12: Artificial Filter Pack Characteristics [20]

Characteristics	Advantages
Clean and Washed (See "clean" in Chapter 2: Definitions & Clarification; Table 2-1)	• Reduces loss of material during development • Protects against impairment of water and aquifer • Requires less development time
Well rounded and uniform grains	• Increases porosity • Increases rate of groundwater flow towards well • Increases well efficiency • Reduces drawdown • Increases yield • Increases effective drawdown • Ensures segregation does not occur during placement or development
90 to 95% quartz grains	• Consists of inert material that should not create water quality problems • Reduces risk of dissolution of grains due to geochemistry of groundwater
Uniformity coefficient of 2.5 or less	• Allows for the proper sized grains to be placed adjacent to the formation. • Allows for larger well screen slots
Filter pack thickness should be no more than 20 cm (8 inches)	• Allows for development techniques to penetrate into the formation

Characteristics	Advantages
Well screen slot size should retain 90% of filter pack grains	• Prevents material from entering well, damaging the pumping equipment and impairing water quality

Best Management Practice – Placing Artificial Filter Pack Material

To place an artificial filter pack around a well screen, the hole needs to be properly sized to allow for the well screen and a sufficiently sized annular space around the well screen. The casing and well screen need to be properly centred in the hole to ensure the person constructing the well places a consistent thickness of filter pack material around the well.

To avoid bridging problems, it is important to place artificial filter pack materials in drilled wells:

- using a tremie pipe,
- with a reverse circulation of fluids, or
- with a direct circulation of fluids.

If a tremie pipe is used, the tremie pipe should be raised slowly as the filter material builds up around the well screen. The distance to the top of the filter pack should be carefully monitored using the tremie pipe or a weighted line inserted through the tremie to feel the top of the filter pack.

If a well casing is being raised to expose a well screen and filter pack to the formation (see the section titled: “Pull Back Method”), the person constructing the well should consider the following to prevent finer material from entering the well screen:

- When using a tremie pipe, the artificial filter pack material should be placed in stages as the casing is pulled back to expose the filter pack and well screen to the formation.
- A sufficient depth of filter pack material should be maintained above the well screen slots as the casing is withdrawn.
- The filter pack level should never drop below the bottom of the outer casing.

For more information on filter pack design see Chapter 9 (pages 409 to 419) and Chapter 10 (pages 486 to 491.) of Groundwater and Wells, Third Edition [21] .

Well Screen Design Considerations for Large Diameter Wells

Typically, coarse sand or gravel is installed below concrete tiles or other types of casing material to prevent sediment from entering the well water in excavated (dug) and some bored wells. This area of the well is typically called a stone bed and has the following characteristics:

- It is usually about 30 cm (12 inches) to 60 cm (24 inches) thick depending on the environment and well design
- It has to be clean, washed and free of contamination

The following sections provide best management practices for the design of well screens for large diameter wells.

Well Screens Using Large Diameter Fibreglass or Galvanized Material

Best Management Practice – Designing a Well Screen Using Fibreglass or Galvanized Casing in Large Diameter Dug and Bored Wells

In most cases groundwater will enter a large diameter well through the open bottom below the well casing. As a result, slotting of the well casing to create a well screen should not be done.

If it is necessary to obtain groundwater through the sides of the well, then it is important for the person constructing the well to contact the manufacturer of the fibreglass or galvanized casing before creating a well screen by perforating or slotting the casing. Persons constructing wells with these materials should have manufacturer determine and confirm if the type of slotting or perforating will potentially weaken or collapse the casing (and void the warranty) or cause impairment of the well water.

Reminder: It is important to follow the manufacturer's specifications when backfilling with clean or washed sand and gravel around the outside of fibreglass and galvanized well screens to prevent collapse and warping in particular environments.

Well Screens Using Large Diameter Concrete Tiles

Where the person constructing the well uses concrete tiles as well casing and well screen in bored or dug wells, the well screen begins at the first unsealed joint in the concrete tiles and ends either at the bottom of the unsealed concrete tiles or any gravel or sand installed below the tiles in the excavated hole.

Best Management Practice – Groundwater Entering Large Diameter Wells Cased with Concrete Tiles

Concrete tiles should be:

- designed to ASTM C478–09 titled Standard Specification for Precast Reinforced Concrete Manhole Sections [22] ,
- designed in a manner sufficient to prevent well collapse, and
- carefully and evenly backfilled on the outside to ensure the tiles remain plumb.

Groundwater should only enter a large diameter well through the open bottom below the deepest concrete tile. Where groundwater is to enter through the open bottom of the concrete tiles, all concrete tile joints should be designed to ASTM C990–09 titled Standard Specification for Joints for Concrete Pipe, Manholes, and Precast Box Sections Using Preformed Flexible Joint Sealants [23] .

Installing Well Screens in Drilling Wells

Properly sized and installed well screens and filter packs reduce the risk of formation collapse and sediment in well water. Failure to install or properly install well screens has been the cause of many problems associated with wells in Ontario such as well plugging, pump and waterline damage, and sediment or granular material in the water supply.

The method of well screen installation is chosen based on practicality and economic feasibility. A particular well design may limit how a well screen can be installed due to:

- aquifer properties,
- methods used to drill the well,
- size and dimensions of the hole, and
- hydraulic conditions,

Some methods of well screen installation include the pull-back, open hole, single string, and bail-down. This section provides general information on all of these methods. The applications, advantages, and disadvantages are summarized in Table 5-13. Outlines of the steps involved in each of these methods are shown following the table.

Table 5-13: Advantages and Disadvantages of Well Screen Installation Methods for Drilled Wells

Methods	Well Construction Equipment	Advantages	Disadvantages

<table>
<tr><th>Methods</th><th>Well Construction Equipment</th><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td>Pull-back</td><td>Best suited for drilling systems that advance the casing as the hole is being constructed. For example:
Cable tool rig,
Air rotary rigs equipped with casing drivers, and
Dual rotary rigs with ring bit and extracting bit systems.</td><td>Can minimize problems caused by:
heaving sediment,
sloughing of the hole walls, and
setting the screen at the wrong depth.
Makes it possible to remove and replace the screen without disturbing the casing and sealant (grout) placed around the casing.

Allows for the installation of a telescopic screen without having to use a temporary casing.</td><td>Heaving formation conditions will create installation problems when using a cable tool or air rotary rig.

The person constructing the well may have to employ one of the following options to set the well screen:
filling the casing with water,
controlling fluid loss using prepared drilling fluid,
using weighted drilling fluids (e.g., barite),
moving tools (e.g., bailers) very slowly up and down the casing to reduce the chances of sediment heaving up into the well casing, or
placing the bottom of the casing to the top of a clay layer under the aquifer, if present.
Where there is significant side-wall friction, this method requires a great deal of force to pull-back the casing.</td></tr>
<tr><td>Open hole (Double string)</td><td>Used in rotary drilling rigs in unconsolidated material.</td><td>Can minimize problems caused from:
Heaving sediment, and
Sloughing of the hole walls.
Makes it possible to remove and replace the screen without disturbing the casing and suitable sealant (grout) placed around the casing.

Allows for the installation of a telescopic screen without having to use a temporary casing.</td><td>Need to use drilling fluid to prevent formation collapse below the well casing.

This may make developing more challenging.</td></tr>
<tr><td>Open hole (Single string)</td><td>Used in narrow drilled wells constructed using rotary drilling rigs in unconsolidated material.</td><td>Minimizes the risk of complications due to heaving formations when using mud rotary.

Well screen (pipe size) can be installed as part of the casing assembly.</td><td>The string offers little column strength and requires support using drilling tools to prevent well screen collapse and crooked wells.

For deeper wells in formations that are prone to collapse, an extra outer diameter casing may have to be installed and grouted for a significant portion of the well.

Well screen cannot be removed independently of the casing.</td></tr>
</table>

Methods	Well Construction Equipment	Advantages	Disadvantages
Bail-down	Used in cable tool rigs and occasionally in rotary drilling rigs in unconsolidated material. Used When: • the pull back method is not desirable or possible (e.g., significant side-wall friction), and • it is difficult to set the screen by single string methods (e.g., high static water level and loose formation materials).	Better than the pull back where significant side-wall friction exists. Better than single string methods where high static water level or loose formation materials exist.	Requires special end fittings for the screen. Requires a special nipple that has right and left hand threads and a coupling with right and left hand threads. Requires annular space to be sealed with suitable sealant before installation can start. May require an extra string of casing to rest on top of the screen and provide extra weight. The lower end of this pipe would likely have to be fitted with a coupling or flange to rest squarely on top of a packer without distorting the packer's shape.
Jetting	Used in jetting wells.	Less expensive than other methods.	Only useful for shallow wells obtaining water from sand formations. Possibility of freezing.
Driving	Used in Driven wells.	Less expensive than other methods. Not a complicated method.	Only useful for shallow wells obtaining water from sand formations. Possibility of freezing. Possibility of creating small annular space (see Chapter 6: Annular Space & Sealing).

Pull-Back Methods of Well Screen Installation [24]

The general steps involved in the pull–back method (Figure 5-16) are as follows:

1. The casing is installed to the full depth of the well. As an alternative, a temporary casing can be installed to the full depth of the well. After the casing is placed in the open hole, any cuttings that settle inside should be carefully cleaned out.

   Reminder: Installing the casing to the bottom of the well is particularly important if a delay is anticipated between drilling and well screen installation. The casing will prevent a partial or full collapse of the formation into the hole.

2. Where a temporary casing has been installed, a permanent smaller diameter well casing is lowered into the temporary casing to the bottom of the hole. A telescopic well screen is pushed inside the permanent casing to the bottom. The bottom of the annular space between the temporary and permanent casings is filled with a filter pack material to a height that extends above the well screen.

   Reminder: A weight should be placed on the bottom of the well screen to stop the well screen from migrating upward while the casing is being pulled back prior to proceeding to Step 3. The weight also creates tension to help the person constructing the well determine the exact position of the well screen during the pull-back procedure.

3.
   a. Where a temporary casing has been installed, the permanent casing is pulled back exposing the well screen and filter pack. Then the temporary well casing is carefully pulled back to expose the well screen and filter pack to the formation.
   b. In cases where a temporary well casing has not been installed, the casing is pulled back (or lifted) far enough to expose the well screen to the water-bearing formation. The bottom of the casing is raised so that the packer near the top of the well screen remains connected and sealed to the casing and to maximize the screen exposure.

   Some methods of lifting the casing include the following:

   - jarring and then lifting the casing with the drilling tools, a bumping block or drive clamp,

- lifting the casing using mechanical or hydraulic jacks, and
- using a pulling ring or spider with wedges or slips to grip and lift the casing. Adding clean water to the well during this process may also help.

4. In situations where no temporary casing has been installed, the well screen will need to be held in place until it is set in the formation. It is important that care be taken to prevent the movement of the well screen during the development and the placement of the suitable sealant in the annular space. See the Tips for Installing Telescopic Well Screens in the next section for further information on preventing the movement of the well screen

   Reminder: In situations where a temporary casing has been installed and lifted to expose the well screen and filter pack, the temporary casing must be fully removed from the well after the suitable sealant has been placed into the annular space (See Chapter 6: Annular Space & Sealing).

Tips For The Installation Of A Telescopic Well Screen

Tips for the installation of a telescopic screen are as follows:

- To ensure extra safety when installing the well screen and maximizing exposure of the well screen to the aquifer, a riser pipe (see Figure 5-14) with K-packers should be attached to the top of the screen. The riser pipe and K-packers will seal the top of the well screen to the bottom of the casing and prevent the well screen from slipping out of the bottom of the well casing. This will also prevent formation material from entering the well between the well screen and casing.
- When developing the well by surging water into and out of the well screen in loose sand formations, the well screen can easily slip out of the bottom of the casing. A riser pipe with multiple K-packers is especially helpful to hold the well screen in place during development of the well.
- To ensure the well screen is placed in the correct location below the well casing, the depths from the ground surface should be accurately and carefully measured.

Figure 5-16: Drilled Well In Overburden-Casing Pull-Back Method To Expose Well Screen

Figure 5-16 shows a cross-sectional diagram of a drilled well in overburden where a casing has been pulled back to expose a well screen. Figure 5-16 shows two steps.

The first step (Before) is shown on the left side of the diagram. The diagram shows a hole is extending vertically into a water-bearing sand and gravel deposit in the subsurface. A casing extends from above the ground surface to the bottom of the hole. An annular space is located between the outside of the casing to the side of the hole. A well screen is shown within the bottom of the casing. The well screen is made up of a K-packer, riser pipe, telescopic screen, coupling and plug. The K-packer is located at the top of the well screen and seals the inner casing and well screen. The riser pipe extends downward from the K-packer to a screen. The screen is located below the riser pipe. The coupling and plug are located below the screen.

The second step (After) is shown on the right side of the diagram. The diagram shows a hole extending vertically into the subsurface. A casing extends from above the ground surface into the subsurface. An annular space is located beside the outside of the casing to the side of the hole. A well screen is shown extending out of the bottom of the casing into the subsurface. The well screen is made up of a K-packer, riser pipe, telescopic screen, coupling and plug. The K-packer is located at the top of the well screen and seals the inner casing and well screen. The riser pipe extends from the K-packer to below the bottom of the casing in the subsurface. The screen is located below the riser pipe in the subsurface. The coupling and plug are located below the screen.

There is text associated with the second step that states “casing raised exposing the screen” and “annular space beside well screen fills in with overburden materials as casing is pulled back, and is then developed to create a filter pack around the screen”.

Reminder: All figures and diagrams are for illustrative purposes only and do not necessarily represent full compliance with other requirements found in the *Wells Regulation*.

Open Hole/Double String Method of Well Screen Installation [25]

This method generally consists of drilling below the casing while maintaining drilling fluid in the well to hold the well open below the casing. A telescopic well screen is installed into the open space below the well casing.

The general steps for this open hole/double string method are as follows:

1. The casing is installed into the well and the annular space is filled with suitable sealant (see Chapter 6: Annular Space & Sealing). The bottom of the casing is slightly below where the top of the well screen will be placed.
2. The casing is filled with drilling fluid (e.g., mud). The well is drilled through the bottom of the well casing to make room for the well screen. In some cases where the formation can be held open (e.g., bedrock, till), drilling fluid is not necessary.

3. A telescopic well screen is lowered or pushed inside the casing to the bottom of the well. Then the “Tips for the installation of a telescopic screen” on this chapter should be followed.
4. If used to hold the hole open, the drilling fluid is removed.
5. The well is then developed.

Figure 5-17: Example of an Open Hole, Double String Method of Screen Installation

Figure 5-17 shows a cross-sectional diagram of a drilled well in overburden where an open hole, double string method is used to install a well screen. Figure 5-17 shows three steps.

The first step (Step 1) is on the left side of the diagram. The diagram shows a hole extending vertically into the subsurface. In the hole, a casing extends from the ground surface to just above the bottom of the hole. A grout shoe is located at the bottom of the casing. Sealant has been placed in the annular space between the outside of the casing and the side of the hole and also in the bottom of the hole below the bottom of the casing and the grout shoe.

The second step (Step 2) is in the centre of the diagram. The diagram shows a deeper hole extending into the subsurface. In the hole, a casing extends from the ground surface to about half of the distance from above the bottom of the hole. An annular space is shown beside the outside of the casing to the side of the hole. Sealant has been placed in the annular space between the outside of the casing and the side of the hole. The remainder of the hole below the bottom of the casing is held open with a drilling fluid.

The third step (Step 3) is on the right side of the diagram. The diagram shows the hole of Step 2 in which a screen and riser pipe has been installed. A well screen is located within the bottom of the casing and extends out of the bottom of the casing to the bottom of the hole. The well screen is made up of a K packer, riser pipe and well screen. The K-packer is located at the top of the well screen and seals the inner casing and well screen. The riser pipe extends from the K-packer to below the bottom of the casing in the subsurface. The screen is located below the riser pipe in the subsurface.

Reminder: The diagram above is not to scale and is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with the requirements found in the *Wells Regulation*.

Open-Hole/Single String Method of Well Screen Installation [26]

The general steps for the open hole/single string method (see Figure 5-18) are as follows:

1. The well screen is attached to the bottom of the first length of casing to be installed in the well as one assembly (i.e., one string). If the well screen is smaller (in diameter) than the casing, it can be welded or threaded to the casing with a flared weld ring or cone adapter. If the well screen is the same size as the casing, it can be welded or threaded directly to the bottom of the casing.
2. Drilling fluid (e.g,, mud) is added into the open hole to prevent any collapse of the sides of the well. As an alternative, an outer temporary casing can be installed to the bottom of the well.
3. The string is installed in the hole to almost the bottom of the well. Where a temporary outer casing is installed, the inner casing, well screen and filter pack are installed within the outer casing and Steps 4 and 6 do not apply.
4. The drilling fluid is thinned to allow the fluid to enter through the slots of the well screen as the string is lowered into the hole. If drilling fluid does not enter into the well screen, the pressure of the drilling fluid could cause the well screen to collapse.
5. Because the string is long and slender it offers little column strength and it requires lateral support to prevent well screen collapse and crooked wells. When this string is installed in an open hole without side support, the string should be suspended from the surface using casing elevators without resting the string on the bottom of the hole.
6. Once installed, the well screen and casing can be filled with water to displace the drilling fluid.
7. For naturally developed wells, the drilling fluid is removed and the fine grained material in the formation is induced to enter the well screen leaving the coarser material on the outside of the well screen. When artificial filter packs are used, the pack material is placed around the well screen and the lower portion of the well casing. The well development process is similar to the natural development of the well. If a temporary outer casing has been installed, the temporary casing is removed to expose the string and filter pack. The well should then be developed.
8. Collapse of the subsurface formation around the string provides lateral support and the full weight of the string can be safely released from the drilling rig.

Reminder: In situations where a temporary casing has been installed and lifted to expose the well screen and filter pack, the temporary casing must be fully removed from the well to meet the requirements for placement of suitable sealant in the annular space (See Chapter 6: Annular Space & Sealing).

Tips For Installing Strings

Tips for string installation are as follows:

- Centralizers can help maintain alignment of the casing and well screen string. Centralizers are recommended for well screens that are greater than 6 m (19.7ft) in length.

- If a clay or silt deposit is located beneath the well screen, it is important to prevent the clay or silt from heaving up next to the screen during well development. Two methodologies to prevent clay or silt from entering the well screen are as follows:

  - When placed around the well screen, an artificial filter pack can act as a formation stabilizer to hold the clay or silt deposit in place during development (see the section titled “Artificial Filter Pack” in this chapter). The grain size of the filter pack should be chosen as described in Table 5-12: Artificial Filter Pack Characteristics.
  - For wells with a large annular space around the well screen, a shale trap or formation packer can be mounted on the bottom of the casing above the well screen. Using this methodology, the formation will collapse around the well screen and below the shale trap or packer. The shale trap or packer will hold the formation in place to prevent heaving of the underlying clay or silt deposit towards the well screen during development [27] .
- For deeper wells in formations that are prone to collapse, a larger diameter outer casing should be installed and grouted for a significant portion of the well. The lower portion of the well should be drilled through the bottom of the outer casing to the desired depth. It is important that the well casing and open portion of the well be filled with drilling fluid. A smaller diameter casing and well screen string is then installed in the well using the same process as described in the general steps.
- To eliminate the need to run two strings of casing to place artificial filter pack material, a pre-packed screen should be used.

Figure 5-18: Single String Method Using Outer Casing

Figure 5-18 shows a cross-sectional diagram of a drilled well in overburden where an open hole, single string method is used to install a well screen. Figure 5-18 shows two steps.

The first step (Before) is on the left side of the diagram. The diagram shows a hole extending vertically into the subsurface. The upper half of the hole is larger than the lower half.

An outer casing extends from above the ground surface to the bottom of the hole. A drive shoe is located on the bottom of the outer casing. An annular space is located beside the outside of the outer casing to the side of the hole.

Within the outer casing is an inner casing with a well screen. This inner casing extends above the ground surface to the bottom of the hole. The well screen is attached to the bottom of the inner casing at the bottom of the hole. There is an annular space between the inner casing and outer casing and between the well screen and the outer casing. A centralizer has been placed at the bottom of the hole between the well screen and outer casing. A second centralizer has been placed in the middle of the hole between the inner casing and the outer casing.

The second step (After) is on the right side of the diagram. The diagram shows a hole extending vertically into the subsurface. The upper half of the hole is larger than the lower half. An outer casing, terminated wih a drive shoe extends from above the ground surface to about half the depth of the hole; below the drive shoe, the hole diameter is more narrow. Within and beyond the outer casing is an inner casing with a well screen. The inner casing, with the screen attached to the bottom, extends above the ground surface to the bottom of the hole. There is an annular space between the inner casing with well screen and the outer casing. There is also an annular space between the inner casing with well screen and the side of the hole below the outer casing. A centralizer has been placed at the bottom of the hole between the well screen and the side of the borehole. A second centralizer has been placed in the middle of the hole between the inner casing and the outer casing. Filter pack has been placed in the annular space around the outside of the inner casing with well screen from the bottom of the well screen to the top of the middle centralizer.

Reminder: The diagram above is not to scale and is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with the requirements found in the *Wells Regulation*.

Bail-Down Method of Well Screen Installation [28]

The objective of the bail–down method is to remove sediment from below the well screen. The removal of the sediment should allow the well screen to settle into position below the bottom of the casing.

The general steps for the bail-down method (see Figure 5-19) are as follows:

1. The casing is installed in the well. The annular space is filled with suitable sealant (see Chapter 6: Annular Space & Sealing). The bottom of the casing is located slightly below where the top of well screen will be placed.
2. The bail-down shoe, heavy nipple and float shoe are assembled in the bottom of a telescopic well screen. The well screen will need a threaded bailing pipe (similar to a riser pipe) with K-packers.
3. The assembly is lifted from the bailing pipe and lowered into the well. Additional lengths of bailing pipe are added to the assembly as it is lowered into the well until the well screen reaches the bottom of the well.

4. A bailer (e.g., a sand pump) is placed inside the bailing pipe. Then the formation material is bailed below the shoe fitting on the well screen. As the formation material is removed, the weight of the well screen and bail pipe causes the well screen to move downward below the bottom of the casing. It is important to carefully measure where the well screen is to be located below the well casing.
5. A weighted and tapered plug is dropped through the bailing pipe to plug the heavy nipple on the bail-down shoe. When the plug is in place, the bail pipe is unthreaded from the well screen and removed from the well. The well is then developed.
6. In other cases, the well screen is not connected to the bailing pipe. Instead, the bailing pipe is fitted with a flange or coupling large enough to press on the neoprene packer at the top of the well screen to hold it in place. To prevent the well screen from sinking below the casing, care needs to be taken as the movement of the well screen cannot be controlled during the bailing process.

Figure 5-19: Bail-Down Method Of Screen Installation

Figure 5-19 shows a cross-sectional diagram of a drilled well in overburden where a bail down method has been used to install a well screen. Figure 5-19 shows two steps.

The first step (Before) is on the left side of the diagram. The diagram shows a hole extending vertically into the subsurface. In the hole, a casing extends from above the ground surface to just above the bottom of the hole. The annular space between the outside of the casing and the side of the hole is sealed. A bailing pipe, leading pipe with k-packer, telescopic screen and a bail-down shoe, heavy nipple and float shoe have been placed within the casing. The bailing pipe extends from above the ground surface to the leading packer and k-packer. The k-packer seals the top of the leading pipe to the inner casing. The telescopic well screen is affixed to the bottom of the leading pipe. The bail-down shoe, heavy nipple and float shoe are affixed to the bottom of the screen. The bail-down shoe, heavy nipple and float shoe extend to the bottom of the hole inside the casing.

An exploded view of the bail-down shoe, heavy nipple and float shoe is shown below and to the left of the first step (Before) diagram. The exploded view shows a cross-sectional diagram of a left handed thread joining the bottom of the well screen to the heavy nipple of the bail-down shoe. A float shoe with holes in its coupling is affixed to the heavy nipple. The bottom of the float shoe has right hand threads.

The second step (After) is on the right side of the diagram. The second step represents the screen bailed down and the coupling and bailing pipe have been removed from the well. The diagram shows a hole extending vertically into the subsurface. In the hole, a casing extends from above the ground surface to the same location as the first step (Before). The annular space between the outside of the casing and the side of the hole is sealed. A leading pipe with k-packer, telescopic screen and a bail-down shoe, heavy nipple and float shoe have been placed within the casing. The k-packer, still located within the casing, seals the top of the leading pipe to the inner casing. Below the bottom of the casing, the telescopic well screen is affixed to the bottom of the leading pipe. The bail-down shoe, heavy nipple and plug are affixed to the bottom of the screen. The bail-down shoe, heavy nipple and plug extend to the bottom of the hole. The screen, heavy nipple and plug extend belong the bottom of the casing into the subsurface.

Reminder: The diagram above is not to scale and is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with the requirements found in the *Wells Regulation*.

Jetting Methods for Well Screen Installation [29]

Jetting methods are typically used to install well screens to depths of no more than 7.5 m (25ft) below the ground surface in sand formations. There are three jetting methods used to install a well screen:

- Jetting adjacent to the casing and well screen (see Figure 5-20)
- Jetting using a wash pipe (see Figure 5-21)
- Jetting and driving using a drop line and chisel-point bit (see Figure 5-22)

Jetting Adjacent To The Casing And Well Screen

The general steps for this method (see Figure 5-20) are as follows:

1. An external pipe is placed adjacent to the casing and well screen string.
2. Water is jetted down through the pipe displacing the formation material.
3. The jetting action allows the string to sink into the sand formation to the required depth.
4. After the jetting pipe has been removed, the well then needs to be developed.

Reminder: See Chapter 6: Annular Space & Sealing for information on the filling of the annular space for a jetted well.

Figure 5-20: Jetting Adjactent to the Casing and Well Screen

Figure 5-20 shows a cross-sectional diagram of jetting a well screen and casing into the subsurface. The diagram shows a hole extending vertically into the subsurface. On the lefthand side of the hole, a casing extends from above the ground surface into the hole. A well screen is attached to the bottom of the casing. A driven-point is attached to the bottom of the screen. The driven-point extends to the bottom of the hole.

On the right side of the hole, adjacent to the casing is a jetting pipe with a jetting/chisel-point bit. This jetting pipe extends from above the ground surface to the bottom of the hole. The jetting/chisel-point bit is attached to the bottom of the jetting pipe. A jetting hose is attached to the top of the jetting pipe.

There are arrows in the diagram demonstrating the flow of water through the jetting hose down the jetting pipe and discharging out of the jetting/chisel-point bit. There are more arrows in the diagram showing the flow of water and subsurface materials flowing up and around the jetting pipe and discharging out of the hole onto the ground surface.

Reminder: The diagram above is not to scale and is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with the requirements found in the *Wells Regulation*.

Jetting Using a Wash Pipe For Well Screen Installation

The general steps for this method (see Figure 5-21) are as follows:

1. A temporary wash pipe is assembled inside the well screen prior to attachment of the well screen to the bottom of the casing. The bottom of the wash pipe ends near the bottom of the well screen. The wash pipe passes up through the well screen and usually continues upward to about 30 cm to 60 cm (12 to 24 inches) into the casing (see Figure 5-21). The wash pipe may extend to the surface in some shallow wells.
2. A coupling is screwed to the lower end of the wash pipe. The coupling rests in a conical seat in the self-closing wash-down fitting, which is equipped with a plastic ball closure.
3. A semi-rigid, plastic ring seal is slipped over the upper end of the wash pipe and is pushed into the top of the well screen. The purpose of this upper ring seal is to close the space around the top of the wash pipe and to direct the jetting water down into the wash pipe.
4. Water is pumped into the casing, through the top of the wash pipe and jets down through the bottom of the self-closing wash-down fitting.
5. In sand formations, the jetting action will allow the string of casing and well screen to sink into the water–bearing formation.
6. To achieve depths greater than 7.5m (25ft), it is important to mix drilling fluid additives with the jetting water to suspend cuttings and stabilize the hole in the event that the circulation of the drilling fluid is interrupted.
7. During this process, some of the jetting water leaks from around the bottom of the wash pipe and flows out through the well screen openings. This prevents fine sand from passing into the well screen and locking the wash pipe inside the well screen.
8. When the well screen has been set at the proper depth, the wash pipe is extracted from the well using a fishing tool.
9. After the wash pipe has been removed, the well is then developed.

Figure 5-21: Jetting Small Diameter Well Screens Into Place by Using a Wash Pipe

Figure 5-21 shows a cross-sectional diagram of jetting a small diameter well screen into place using a wash pipe.

The diagram shows a hole extending vertically into the subsurface. The diagram shows the wash pipe and other equipment working to create the well. A casing extends from above the ground surface into the hole. A well screen is attached to the bottom of the casing. A wash pipe extends into the top of the casing and into the well screen. At the bottom of the wash pipe, a self-closing, wash-down fitting ball has been attached to allow water to discharge out of the wash pipe but prevent subsurface materials from entering into the well. A pin to retain the self-closing wash-down fitting ball is affixed to the ball. The bottom of the wash pipe has a coupling that rests in a conical seat. Near the upper portion of the casing in the hole, a ring seal has been placed between the wash pipe and the inside of the casing.

There are arrows in the diagram demonstrating the flow of water from a pump through the wash pipe and discharging out of the wash pipe into the hole. There are more arrows in the diagram showing the flow of water and subsurface materials flowing up and around the casing and discharging out of the hole onto the ground surface.

Reminder: The diagram above is not to scale and is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with the requirements found in the *Wells Regulation*.

Jetting and Driving Using a Drop Line and Chisel-Point Bit for Well Screen Installation

The general steps for this method (see Figure 5-22) are as follows:

1. A chisel-point bit is attached to the bottom of a drop line. The drop line is placed within the well casing.
2. Water is jetted through the drop line and the jetting pipe is rotated by hand and adjusted vertically. During jetting, material is washed upward between the inside of the casing and the outside of the drop line. The drop line and bit are also intermittently driven during the process. During the process, the casing will move downward to the required depth.
3. The drop line is removed and a telescopic well screen point is inserted. Then, the well screen point is driven out the bottom of the casing. As an alternative, the well screen can be inserted into the bottom of the casing. Then the pull-back method can be used to lift the well casing and expose the well screen to the formation.

Figure 5-22: Screen Installation Using Jetting and Driving Simultaneously

Figure 5-22 shows a cross-sectional diagram of jetting and driving a well screen simultaneously.

The diagram shows the drop pipe, casing and other equipment working to create a well. The diagram shows a hole extending vertically into the subsurface. A casing with a drive shoe extends from above the ground surface into the hole. The drive shoe is attached to the bottom of the casing. A horizontal discharge pipe is attached to the upper portion of the casing above the ground surface.

A jetting pipe extends from above the top of the casing and horizontal discharge pipe into the casing. The bottom of the jetting pipe extends to the bottom of the casing. A chisel-point bit is attached to the bottom of the jetting pipe and is located below the casing.

Above the ground surface, a swivel is attached to the top of the jetting pipe. A jetting hose is attached to the top of the jetting pipe. A vertical cable is shown affixed to the top of the swivel to hold up the jetting hose and jetting pipe above the ground surface.

There are arrows in the diagram demonstrating the flow of water through the jetting hose down the jetting pipe and discharging out of the chisel-point bit. There are more arrows in the diagram demonstrating the flow of water and subsurface materials flowing up and around the jetting pipe within the casing. The arrows in the diagram water demonstrate water and subsurface materials flowing out of the casing into the horizontal discharge pipe and discharging out of the hole onto the ground surface.

Reminder: The diagram above is not to scale and is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with the requirements found in the *Wells Regulation*.

Driving Methods of Well Screen Installation

Driving methods are typically used to install well screens to depths of no more 7.5 m (25ft) below the ground surface in sand formations. There are 2 common driving methods used to install a well screen:

- driving a telescopic well screen below the casing, and
- driving a casing and well screen string

Driving A Telescopic Well Screen Below The Casing

1. A casing is installed within the water bearing formation.
2. A telescopic well screen point is inserted with a drive bar. The well screen is driven to expose it below the bottom of the casing while maintaining the seal with the casing.

Driving A Casing And Well Screen String

1. Using a drive bar, the casing and well screen string are driven to the water bearing formation.
2. As an alternative, hollow stem augers are placed into the ground to the water bearing formation. The casing and well screen string are placed inside the hollow stem augers. The well screen and a portion of the casing are driven with a drive bar below the augers. As the augers are backed out of the hole, the annular space between the augers and the string is filled with an artificial filter pack, where necessary, and a suitable sealant.

Tips When Driving Well Screens

The following tips should be considered when driving a well screen:

- Driving methods requires additional care in sealing the joint between the driven point well screen and casing and between other casing joints.
- Driving methods requires additional care to ensure that the impact of driving does not damage the casing, well screen or joints.

- If a boulder, cobble or other large obstacle is encountered the casing and well screen string may be damaged or deflected. The string may have to be pulled and the hole properly abandoned (See Chapter 14: Abandonment: When to Plug and Seal Wells and Chapter 15: Abandonment: How To Plug and Seal Wells). The string will have to be relocated.
- It is important to use commercially manufactured steel driven points to penetrate the formation.

Reminder: For further information see Figure 5-29 in this chapter, and the “Grout Placement – Annular Space for Driven Points” section in Chapter 6: Annular Space & Sealing.

Diagrams of Common Types of Wells

Reminder: Figures 5-23 to 5-30 show cross sectional illustrations and relevant graphics for various types of wells that have been discussed in this chapter. The illustrations include the minimum size of the hole, the length of casing, the type of well screen and annular space filling materials around the well screen.

Reminder: All figures and diagrams are for illustrative purposes only and do not necessarily represent full compliance with other requirements found in the *Wells Regulation* (e.g., well covering during construction).

Reminder: For details on the requirements involved in sealing the on the annular space and completing the well, refer to the following chapters in this manual:

- Chapter 6: Annular Space & Sealing
- Chapter 7: Completing the Well’s Structure

Each of the wells shown in Figures 5-23 to 5-30 may encounter conditions that require specialized design or construction. For example:

- flowing artesian conditions
- presence of gas
- pucking and blowing (breathing) conditions where the well and aquifer formation are significantly affected by changes in atmospheric pressure

Reminder: The illustrations and graphics may not depict every circumstance.

Figure 5-23: Drilled Well In Overburden - Well Screens That Are Artificially Packed/Naturally Developed

The left side of Figure 5-23 shows a cross-sectional diagram of a drilled well in overburden with a well screen. The bottom of the well is completed with a well screen that is located in a water bearing sand and gravel overburden. A plug is located on the bottom of the well screen. The well screen is attached to the casing. The casing extends vertically from the top of the well screen (the water intake zone) to above the ground surface. There is text adjacent to the casing in the diagram. The text indicates that the casing is required to extend from the ground surface to at least 6 metres (19.7 feet) below the ground surface. There is an annular space around the casing and well screen. It is a requirement that the clean washed sand and gravel can be no closer than 6 metres (19.7 feet) to the ground surface.

There is a circle drawn around the bottom of the well that includes the well screen, the overburden near the well screen and the casing just above the well screen. There is text that states “see exploded views A, B and C” with an arrow pointing from the text to the circle.

The right side of Figure 5-23 shows three exploded views (A, B and C).

Exploded View A shows a cross-sectional diagram of a well screen installed using an artificial sand or gravel pack. The diagram shows the bottom of a well completed with a well screen that is located in the natural water bearing sand and gravel overburden. A plug is located on the bottom of the well screen. The well screen is attached to the bottom of the casing. There is an annular space around the outside of the casing and well screen. The annular space around the outside of the well screen is filled with cleaned wash sand or gravel.

Exploded View B shows a cross-sectional diagram of a well screen installed using natural development. The diagram shows the bottom of a well completed with a well screen that is located in the natural water bearing sand and gravel overburden. A plug is located on the bottom of the well screen. The well screen is attached to the bottom of the casing. There is an annular space around the outside of the casing but not around the screen. The overburden has collapsed around the outside of the well screen. The overburden around the well screen is developed to remove finer subsurface material and allow groundwater to enter the well through the well screen.

Exploded View C shows a cross-sectional diagram of a well screen installed using natural development and a shale trap. The diagram shows the bottom of the well completed with a well screen that is located in the natural water bearing sand and gravel overburden. A plug is located on the bottom of the well screen. The well screen is attached to the casing. A shale trap is located around the outside the bottom of the casing. There is an annular space around the outside of the casing and immediately above the shale trap. The overburden

has collapsed around the outside of the well screen. The overburden around the well screen is developed to remove finer subsurface material and allow groundwater to enter the well through the well screen.

- The casing must extend to ≥ 6 m (19.7ft) below ground surface unless the only aquifer is ≤ 6 m (19.7ft) below ground surface in which case:
  - The casing must extend at least 2.5 m (8.2 ft) below ground surface, and
  - The well depth must be at least 3 m (10 ft) below ground surface
- The hole diameter must be at least 7.6 cm (3 inches) greater than the final outer casing for at least 6 m (19.7ft) from the ground surface or the full depth of the well (whichever is less).
- If centralizers are used with rotary equipment or a breakaway guide is used with cable tool equipment, the hole diameter must be at least 5.1 cm (2 inches) greater than the final outer casing for at least 6 m (19.7ft) from the ground surface or the full depth of the well (whichever is less).
- This applies to all wells other than wells constructed by the use of a driven or a jetted point, dug wells and bored wells with conrete casing.

Reminder: Refer to Table 5-11 in this chapter for a picture of a shale trap.

Reminder: The diagram above is not to scale and is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with the requirements found in the *Wells Regulation*.

Figure 5-24: Drilled Well - Without Well Screen

The left side of Figure 5-24 shows a cross-sectional diagram of a drilled well in overburden without using a well screen.

The diagram shows a well completed into gravel overburden. The well is completed with a casing that extends vertically through overburden into gravel overburden. The casing extends from the water intake zone to above the ground surface. There is text adjacent to the casing on the diagram. The text indicates that the casing is required to extend from the ground surface to at least 6 metres (19.7 feet) below the ground surface. There is an annular space around the outside of the casing from the ground surface to the top of the gravel.

There is a circle drawn around the bottom of the well that includes the bottom of the casing and the overburden near the casing on diagram on the left side of Figure 5-24. There is text that states “see exploded views A and B” with an arrow from the text to the circle.

The two exploded views (A and B) are located on the right side of Figure 5-24.

Exploded View A shows a cross-sectional diagram of the bottom portion of the casing driven into an aquifer. The diagram shows the bottom of the well completed with a casing. The bottom of the casing is installed into the water bearing gravel overburden. There is an annular space around the outside of the casing above the gravel overburden.

Exploded View B shows a cross-sectional diagram of the bottom portion of the casing driven into an aquifer and a shale trap attached. The diagram shows the bottom of the well completed with a casing. The bottom of the casing is open to the formation. The bottom of the casing is installed into the water bearing gravel overburden. A shale trap is located around the outside of the casing and close to the bottom of the casing. There is an annular space around the outside of the casing and immediately above the shale trap.

- The casing must extend ≥ 6 m (19.7ft) below ground surface unless the only useful aquifer is ≤ 6 m (19.7ft) below ground surface in which case:
  - the casing must extend at least 2.5 m (8.2ft) below ground surface, and
  - the well depth must be ≥ 3 m (10 ft) below ground surface.
- The hole diameter must be least 7.6 cm (3 inches) greater than the final outer casing for at least 6 m (19.7ft) from the ground surface or the full depth of teh well (whichever is less).
- If centralizers are used with rotary equipment or a breakaway guide is used with cable tool equipment, the hole diameter must be at least 5.1 cm (2 inches) greater than the final outer casing for at least 6 m (19.7ft) from the ground surface or the full depth of the well (whichever is less).
- This applies to all wells other than wells constructed by the use of a driven or jetted point, dug wells and bored wells with concrete casing.
- In this example, the casing has been driven below the bottom of teh annular space.

Reminder: Refer to Table 5-11 in this chapter for a picture of a shale trap.

Reminder: The diagram above is not to scale and is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with the requirements found in the *Wells Regulation*.

Figure 5-25: Examples Of Drilled Wells In Bedrock

Figure 5-25 shows a cross-sectional diagram of three wells (A, B and C) completed in bedrock.

The three wells are drilled through a layer of overburden underlain by weathered bedrock. The weathered bedrock is underlain by solid (or consolidated) bedrock.

The well on the left of the diagram is example “A”. The well is completed with a casing that extends vertically from above the ground surface through overburden to the top bedrock. The bottom of the casing is sealed into the bedrock immediately below the weathered bedrock to prevent impairment of the well water quality in the bedrock. The well is drilled into the solid bedrock as an open hole as the bedrock has enough strength to not collapse into the hole. There is an annular space around the outside of the casing from the ground surface to an elevation above the top of the weathered bedrock in the overburden.

The well in the middle of the diagram is example “B” and is considered “better” than example “A”. The well is completed with a casing that extends vertically from above the ground surface through overburden to the top bedrock. Unlike scenario A, a drive shoe (thicker piece of casing) is attached to the bottom of the casing and it is the driveshoe that is seated and sealed in the bedrock but immediately below the weathered zone. Beyond the casing and the driveshoe, the well is drilled into the solid bedrock as an open hole as the bedrock has enough strength to not collapse into the hole. There is an annular space around the outside of the casing from the ground surface to the top of the consolidated rock.

The well on the right side of the diagram is example “C” and is considered the “best” of examples “A”, “B” and “C”. The well is completed with a casing that extends vertically from above the ground surface through overburden to the bedrock. A drive shoe (thicker piece of casing) is attached to the bottom of the casing string. The bottom of the casing, with the drive shoe, is sealed and seated into the solid bedrock. Below the casing, the well is drilled into the solid bedrock as an open hole as the bedrock has enough strength to not collapse into the hole. There is an annular space around the outside of the casing from the ground surface to just above the bottom of the drive shoe.

- The casing must extend to ≥ 6 m (19.7ft) below ground surface unless the only useful squifer is ≤ 6 m (19.7ft) below ground surface in which case:
  - the casing must extend at least 2.5 m (8.2 ft) below ground surface, and
  - the well depth must be ≥ 3 m (10 ft) below ground surface.
- The hole diameter must be at least 7.6 cm (3 inches) greater than the final outer casing for at least 6 m (19.7ft) from the ground surface or the full deth of the well (which is elss).
- If centralizers are used with rotart equipment or a breakaway guide is used with cable tool equipment, the hole diameter must be at least 5.1 cm (2 inches) greater than the final outer casing for at least 6 m (19.7ft) from the ground surface or the full depth of the well (whichever is less.)
- This applies to all wells otehr than wells constructed by the use of a driven or jetted point, dug wells and bored wells with concrete casing.
- In the example, the casing in “A” has been driven below the bottom of the annular space.

Reminder: The diagram above is not to scale and is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with the requirements found in the *Wells Regulation*.

Reminder: To verify the casing is sealed into the bedrock see the “Best Management Practice – Ensuring the Casing is Sealed in the Bedrock” of this chapter.

Figure 5-26: Drilled Well in Overburden - Natural Development, Casing Pull-Back Method to Expose Well Screen

Figure 5-26 shows a cross-sectional diagram of a drilled well in the overburden using natural development, casing pulled back method. Figure 5-26 shows two steps.

The first step (Before) is shown on the left side of the diagram. The diagram shows a hole is extending vertically into a water-bearing sand and gravel deposit in the subsurface. A casing extends from above the ground surface to the bottom of the hole. An annular space is located between the outside of the casing to the side of the hole. A well screen is shown within the bottom of the casing. The well screen is made up of a K-packer, riser pipe, telescopic screen, coupling and plug. The K-packer is located at the top of the well screen and seals the inner casing and well screen. The riser pipe extends downward from the K-packer to a screen. The screen is located below the riser pipe. The coupling and plug are located below the screen.

The second step (After) is shown on the right side of the diagram. The diagram shows a hole extending vertically into the subsurface. A casing extends from above the ground surface into the subsurface. An annular space is located beside the outside of the casing to the

side of the hole. A well screen is shown within the bottom of the casing and extends out of the bottom of the casing into the subsurface. The well screen is made up of a K-packer, riser pipe, telescopic screen, coupling and plug. The K-packer is located at the top of the well screen and seals the inner casing and well screen. The riser pipe extends from the K-packer to below the bottom of the casing in the subsurface. The screen is located below the riser pipe in the subsurface. The coupling and plug are located below the screen. A portion of the riser pier, the telescopic screen and plug are located beyond the bottom of the casing allowing groundwater to enter into well through the screen.

There is text associated with the second step that states "casing raised exposing the screen" and "annular space beside well screen fills in with overburden materials as casing is pulled back, and is then developed to create a filter pack around the screen".

- The casing must extend to ≥ 6 m (19.7ft) below ground surface unless the only useful aquifer is ≤ 6 m (19.7ft) below ground surface in which case:
    - the casing must extend at least 2.5 m (8.2 ft) below ground surface, and
    - the well depth must be ≥ 3 m (10 ft) below ground surface.
- The hole diameter must be at least 7.6 cm (3 inches) greater than the final outer casing for least 6 m (19.7ft) from the ground surface or the full depth of the well (which is less.)
- If centralizers are used with rotary equipment or a breakaway guide is used with cable tool equipment, the hole diameter must be at least 5.1 cm (2 inches) greater than the final outer casing for at least 6 m (19.7ft) from the ground surface or the full depth of the well (whichever is less).

Reminder: The diagram above is not to scale and is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with the requirements found in the *Wells Regulation*.

Figure 5-27: Bored Well With Concrete Casing

Figure 5-27 shows a cross-sectional diagram of a bored well with concrete casing completed into overburden.

The bored well extends into the subsurface below the water table as represented by a dotted horizontal line. The bored well consists of concrete tiles, arranged vertically on top of one another, from above the ground surface into an aquifer in the overburden. The joints and seams in the concrete tiles are required to be permanently watertight to the water intake zone. These concrete tiles with sealed joints are considered casing. The diagram shows two concrete tiles in the water intake zone that are unsealed. There is text adjacent to the casing on the diagram. The text indicates that the casing is required to extend from the ground surface to at least 6 metres (19.7 feet) below the ground surface. If the well extends into the bedrock, the casing is required to extend to the competent bedrock surface. There is an annular space around the concrete tiles including the unsealed tiles (water intake zone or well screen). The annular space from the water table to the bottom of the concrete tiles is filled with cleaned wash sand or gravel. The clean washed sand and gravel can be no closer than 6 metres (19.7 feet) to the ground surface.

- The casing must extend ≥ 6 m (19.7ft) below ground surface unless the only useful aquifer is ≤ 6 m (19.7ft) below ground surface in which case:
    - the casing must extend at least 2.5 m (8.2 ft) below ground surface, and
    - the well depth must be ≥ 3 m (10 ft) below ground surface.
- The hole must be at least 15.2 cm (6 inches) greater than the casing's outer diameter from the land surface to a depth of 2.5 m (8.2 ft).
- The hole must be at least 7.6 cm (3 inches) greater than the casing's outer diameter from 2.5 m (8.2 ft) to at least 6 m (20 ft) below the ground surface or the full depth of the well (whichever is less)
- Sand and gravel must be installed from at least the top of the water intake zone or screen to no closer than 6 m (20ft) below the land surface unless the only useful aquifer available necessitates a shallower well in which case clean, washed sand or gravel must be installed no closer than 2.5 m (8.2 ft) from the ground surface.

Reminder: The diagram above is not to scale and is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with the requirements found in the *Wells Regulation*.

Figure 5-28: Dug Well

Figure 5-28 shows a cross-sectional diagram of dug well.

The diagram shows a dug well completed into overburden. The well consists of casing that extends vertically from above the ground surface to below the water table in the overburden. The joints and seams in the casing are required to be permanently watertight to the water intake zone. The diagram shows an unsealed joint between two pieces of casing in the water intake zone. The bottom of the

casing is open to the formation. There is text adjacent to the casing on the diagram. The text indicates that the casing is required to extend from the ground surface to at least 6 metres (19.7 feet) below the ground surface. The text also indicates that if the well extends into the bedrock, the casing is required to extend to the competent bedrock surface. An area below the casing is filled with clean, washed sand or gravel. There is an annular space around the outside of the casing. The annular space from the bottom of the casing to 2.5 metres (8.2 feet) below the ground surface is filled with clean, washed sand or gravel.

- The casing must extend ≥ (19.7ft) below ground surface unless the only useful aquifer is ≤ 6 m (20ft) below ground surface in which case:
  - the casing must extend at least 2.5 m (8.2 ft) below ground surface, and
  - the well depth must be ≥ 3 m (10 ft) below ground surface.
- All concrete titles with joints that are not sealed and are installed to filter out particulate matter considered well screen (water intake zone).
- Sand or gravel can be replaced with native material (soil) that was excavated from the hole, if the well is not constructed in a contaminated area and the horizons of soil are excavated separately, stored separately, kept free from contamination and backfilled in the same relative positions that they orginally occupied.

Reminder: The diagram above is not to scale and is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with the requirements found in the *Wells Regulation*.

Figure 5-29: Driven Point Well

Figure 5-29 shows a cross-sectional diagram of driven-point well.

The diagram shows a driven-point well completed into the subsurface. The well consists of casing that extends vertically from above the ground surface to below the water table in the water bearing sand and gravel overburden. The casing extends to the water intake zone. A well screen is attached to the bottom of the casing and a drive-point is attached to the bottom of the well screen. An airtight cap is located at the top of the casing. The casing is high enough above the ground surface to affix a well tag above the ground surface. Below the frost line a horizontal water line connects to the casing. An excavation zone has been created to connect the horizontal waterline to the casing.

- The casing must extend ≥ 6 m (19.7ft) below ground surface unless the only useful aquifer is ≤ 6 m (19.7ft) below ground surface in which case:
  - the casing must extend at least 2.5 m (8.2 ft) below ground surface, and
  - the well depth must be ≥ 3 m (10 ft) below ground surface.

Reminder: The diagram above is not to scale and is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with the requirements found in the *Wells Regulation*.

Figure 5-30: Jetted Well

Figure 5-30 shows a cross-sectional diagram of a jetted point well.

The diagram shows a jetted point well completed into the overburden. The well consists of casing that extends vertically from above the ground surface to below the water table in the water bearing sand and gravel overburden. The casing extends to the water intake zone. A well screen is attached to the bottom of the casing and a drive-point is attached to the bottom of the well screen. An airtight well cap is located at the top of the casing. The casing is high enough above the ground surface to affix a well tag above the ground surface. Below the frost line a horizontal water line connects to the casing. An excavation zone has been created to connect the horizontal waterline to the casing.

- The casing must extend ≥ 6 m (19.7ft) below ground surface unless the only useful aquifer is ≤ 6 m below ground surface in which case:
  - the casing must extend at least 2.5 m (8.2 ft) below ground surface, and
  - the well depth must be ≥ 3 m (10 ft) below ground surface.

Reminder: The diagram above is not to scale and is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with the requirements found in the *Wells Regulation*.

6. Annular Space & Sealing

Chapter Description

This chapter covers the construction process involved in sealing the well casing into the hole to ensure that there is no movement of water or other materials along the annular space as required by the *Wells Regulation*.

Regulatory Requirements - Annular Space & Sealing Of A New Well

Relevant Sections - The *Wells Regulation*

- Casing – Subsections 13(12) and 13(20)
- Annular Space – Sections 14 and 14.1 to 14.6

The Requirements - Plainly Stated

The *Wells Regulation* requires the following regarding creation and sealing of the annular space for new well construction:

Annular space
: means an open space between a casing or well screen and the side of a well, and includes space between overlapping casings within the well

Subsurface Movement for New Well Construction

The person constructing the well must ensure that any annular space, other than the annular space surrounding the well screen, is sealed to prevent any movement of water, natural gas, contaminants or other material between subsurface formations or between subsurface formations and the ground surface by means of the annular space.

Sealing Annular Space for New Wells

See Table 6-1A and Table 6-1B in this chapter for a summary of the requirements outlined in the *Wells Regulation* that the person constructing the well must follow when creating and filling the annular space for a new well construction other than jetted wells or wells constructed by use of a driven point.

New Wells Constructed by Use of a Driven Point

A person constructing a well by use of a driven point must ensure that any annular space is filled to the ground surface using a method and material approved by the Director (see “Grout Placement – Annular Space for Driven Points” in this chapter).

New Wells Constructed by Jetting

The requirements in Table 6-1A and Table 6-1B do not apply to a new well that is constructed by jetting. The annular space sealing requirements in “Subsurface Movement for New Well Construction” on the previous page apply to a new well constructed by jetting equipment.

Sealing Casing in Bedrock for New Drilled Wells

If the aquifer is located in a bedrock zone that is not weathered, the person constructing the well must ensure that the casing of a new drilled well is sealed into the bedrock with suitable sealant to prevent impairment of the quality of the groundwater and the water in the well.

Reminder: For clarification of the term “weathered bedrock” and “suitable sealant” see Chapter 2: Definitions & Clarifications, Table 2-2.

Sealing Annular Space between Casings

The person constructing the well must ensure that the annular space between casings of different diameters is sealed with suitable sealant to prevent the entry of surface water or other foreign materials into the well.

New Well Completed with a Permanent Outer Casing – Double Walled Casing

Some new wells are completed with a casing surrounded by a permanent casing of larger diameter (i.e., a permanent outer casing). The person constructing the well must ensure that the annular space around and between the inner casing(s) and the permanent outer casing for a new well is sealed, as follows:

- All construction and sealing requirements for the corresponding well construction method in Table 6-1A and Table 6-1B apply with necessary modifications to the well's annular space on the outside of the outer casing. As a necessary modification, the depth of the annular space must extend from the ground surface to at least the bottom of the permanent outer casing or 6 m (19.7ft), whichever is less unless.
- If any groundwater is entering the annular space between the inner casing(s) and the permanent outer casing, the entire annular space between the casings must be sealed, with necessary modifications, in accordance to the minimum requirements of Table 6-1A and Table 6-1B. This requirement does not apply to a well pit or a well constructed by the use of a driven point.
- In all cases, the annular space between casings of different diameters must be sealed with suitable sealant to prevent the entry of surface water and other foreign materials into the well.

Annular Space below the Permanent Outer Casing

Person Constructing a Well

Although the person constructing a well is not specifically required to seal the casing below the permanent outer casing; the person must do what is necessary as the *Ontario Water Resources Act* prohibits every person from discharging or causing or permitting the discharge of any material of any kind into any waters that may impair the quality of any waters. This includes prohibiting contaminated groundwater from impairing the quality of other groundwater zones when constructing a well.

Well Owner

Persons using the above professional judgment and the well owner should be aware of the following requirement.

If the well acts as a pathway for the movement of:

- natural gas,
- contaminants, or
- other materials

between subsurface formations (including aquifers) or between the ground surface and a subsurface formation and where the movement may impair the quality of any waters, the person abandoning the well, often the well owner, must to do one of the following:

- take measures to prevent the movement of the above materials and ensure the measures are functional at all times, or
- immediately abandon the well

See Chapter 14: Abandonment: When to Plug & Seal Wells and Chapter 15: Abandonment: How to Plug & Seal Wells of this manual for further information on abandonment.

Reminder: Definitions for sealant, watertight, tremie pipe and other relevant terms are stated in Chapter 2: Definitions & Clarifications.

Reminder: See Figures 6-6 to 6-13 for illustrations of the sealing requirements described in Table 6-1A and Table 6-1B for most common wells.

Table 6-1A: Annular Space and Sealing Requirements for New Drilled and Other [*] Wells and Well Pits for Wells with Casing

	Drilled Well or any other Well ≥ 6 m (19.7ft) deep that is not listed on Table 6-1A or B (except jetted wells & wells constructed using driven points)	**Drilled Well or any other Well ≤ 6 m (19.7ft) deep that is not listed on Table 6-1A or B (except jetted wells & wells constructed using driven points)**	**New Well Pit (see Chapter 9: Equipment Installation)**

	Drilled Well or any other Well ≥ 6 m (19.7ft) deep that is not listed on Table 6-1A or B (except jetted wells & wells constructed using driven points)	Drilled Well or any other Well ≤ 6 m (19.7ft) deep that is not listed on Table 6-1A or B (except jetted wells & wells constructed using driven points)	New Well Pit (see Chapter 9: Equipment Installation)
Minimum Diameter of Hole Greater Than Outer Casing Diameter to Create Annular Space	• Minimum Diameter is ≥ 7.6 cm (3 inches)	• Minimum Diameter is ≥ 7.6 cm (3 inches)	• Minimum Diameter is ≥ 7.6 cm (3 inches)
Minimum Diameter of Hole Greater Than Outer Casing Diameter to Create Annular Space	• Minimum Diameter is ≥ 5.1 cm (2 inches) • If centralizers are attached to casing ≥ 6 m (19.7ft) below the ground surface using rotary drilling equipment OR • If breakaway guide is attached 2 m (6.3ft) above the bottom of any casing using cable tool equipment	• Minimum Diameter is ≥ 5.1 cm (2 inches) • If centralizers are attached to casing ≥ 6 m (19.7ft) below the ground surface using rotary drilling equipment OR • If breakaway guide is attached 2 m (6.3ft) above the bottom of any casing using cable tool equipment	• Minimum Diameter is ≥ 7.6 cm (3 inches)

Minimum Depth of Annular Space below Ground Surface at the Diameter Specified in the Previous Row [**]	• ≥ 6 m (19.7ft)	• Where no well screen is installed:
		  ◦ bottom of well
		• If well screen installed:
		  ◦ bottom of well screen, and
		  ◦ top of well screen must not be closer to ground surface than 2.5 m (8.2ft)
			• Bottom of well pit

Bottom of Filter Pack Material around Well Screen if present	• Bottom of well	• Bottom of well	• None
Type of Annular Filter Pack Material around Well Screen	• Clean, washed gravel or sand placed during or after placement of well screen and casing or • Clean, washed gravel or sand developed after placement of suitable sealant using surging to remove fine grained soils	• Clean, washed gravel or sand placed during or after placement of well screen and casing or • Clean, washed gravel or sand developed after placement of suitable sealant using surging to remove fine grained soils	• None
Maximum Top of Annular Filter Pack Material around Well Screen and Well Casing	• At least the top of well screen but no closer to ground surface than 6 m (19.7ft) • Only applies where well screen is present	• At least the top of well screen, but no closer to ground surface than 2.5 m (8.2ft) • Only applies where well screen is present	• None

	Drilled Well or any other Well ≥ 6 m (19.7ft) deep that is not listed on Table 6-1A or B (except jetted wells & wells constructed using driven points)	Drilled Well or any other Well ≤ 6 m (19.7ft) deep that is not listed on Table 6-1A or B (except jetted wells & wells constructed using driven points)	New Well Pit (see Chapter 9: Equipment Installation)
Annular Seal Material around Casing in remaining Open Annular Space	• Suitable sealant placed using tremie pipe with bottom end of pipe immersed in rising accumulation of sealant. • Sealant particle size must not be subject to bridging for a well that has a minimum hole diameter that is not less than 5.1 cm (2 inches) more than the outer casing diameter. The casing also must be properly aligned in the hole. • If no well screen is used, suitable sealant must be used to fill the space from the bottom of the annular space adjacent to the casing up to ground surface.	• Suitable sealant placed using tremie pipe with bottom end of pipe immersed in rising accumulation of sealant. • Sealant particle size must not be subject to bridging for a well that has a minimum hole diameter that is not less than 5.1 cm (2 inches) more than he outer casing diameter. The casing also must be properly aligned in the hole. • If no well screen is used, suitable sealant must be used to fill the space from the bottom of the annular space adjacent to the casing up to ground surface.	• Suitable sealant with structural strength to support weight of persons and vehicles
Where Cement Is Used in Suitable Sealant Mixture	• Allow cement to cure to manufacturer’s specifications or for 12 hours whichever is longer. If cement mixture settles, the suitable sealant shall be topped up to the original level	• Allow cement to cure to manufacturer’s specifications or for 12 hours whichever is longer. If cement mixture settles, the suitable sealant shall be topped up to the original level	• Allow cement to cure to manufacturer’s specifications or for 12 hours whichever is longer. If cement mixture settles, the suitable sealant shall be topped up to the original level

Table 6-1B: Annular Space And Sealing Requirements for New Bored Wells with Concrete Casing and Dug (or Excavated) Wells

	Bored Well with Concrete Casing ≥ 6 m (19.7ft) deep	Bored Well with Concrete Casing ≤ 6 m (19.7ft) deep	Dug (or Excavated) Well
Minimum Diameter of Hole Greater than Outer Casing Diameter to Create Annular Space	• From ground surface to ≥ 2.5 m (8.2ft) below ground surface • Minimum Diameter is ≥ 15.2 cm (6 inches)	• From ground surface to ≥ 2.5 m (8.2ft) below ground surface • Minimum Diameter is ≥ 15.2 cm (6 inches)	• None
Minimum Diameter of Hole Greater than Outer Casing Diameter to Create Annular Space	• From ≥ 2.5 m (8.2ft) below the ground surface • Minimum Diameter is ≥ 7.6 cm (3 inches)	• From ≥ 2.5 m (8.2ft) below the ground surface • Minimum Diameter is ≥ 7.6 cm (3 inches)	• None

	Bored Well with Concrete Casing ≥ 6 m (19.7ft) deep	Bored Well with Concrete Casing ≤ 6 m (19.7ft) deep	Dug (or Excavated) Well
Minimum Depth of Annular Space below Ground Surface at the Diameter Specified in the Previous Row [**]	• ≥ 6 m (19.7ft)	• Where no well screen is installed: ◦ bottom of well • If well screen installed: ◦ bottom of well screen, and ◦ top of well screen must not be closer to ground surface than 2.5 m (8.2ft) [**]	• None
Bottom of Filter Pack Material around Well Screen if Present	• Bottom of well screen	• Bottom of well screen	• Bottom of well
Type of Annular Filter Pack, Granular or Native Material	• Clean, washed gravel or sand deposited only after placement of well screen and casing • Only applies if well screen is present	• Clean, washed gravel or sand deposited only after placement of well screen and casing • Only applies if well screen is present	• Clean, washed gravel, or • Clean, washed sand, or • Native materials (soil) excavated from the well only if they are not from a contaminated area and the major horizons of soil are excavated and stored separately, kept free of contamination and then backfilled within the annular space in the same relative position that the horizon originally occupied.
Maximum Top of Annular Filter Pack Material around Well Screen and Well Casing	• At least the top of well screen but no closer to ground surface than 6 m (19.7ft) below ground surface • Only applies where well screen is present	• At least the top of well screen but no closer to ground surface than 2.5 m (8.2ft) below ground surface • Only applies where well screen is present	• No closer to ground surface than 2.5 m (8.2ft) below ground surface
Annular Seal Material around Casing in Remaining Open Annular Space from Filter Pack, Granular or Native Material to ≥ 2.5 m (8.2ft) below Ground Surface	• Suitable sealant placed using tremie pipe with bottom end of pipe immersed in rising accumulation of sealant • If no well screen is used, suitable sealant must be used to fill the space from the bottom of the well up to this depth.	• Suitable sealant placed using tremie pipe with bottom end of pipe immersed in rising accumulation of sealant • If no well screen is used, suitable sealant must be used to fill the space from the bottom of the well up to this depth.	• Suitable sealant that has structural strength to support weight of persons and vehicles

	Bored Well with Concrete Casing ≥ 6 m (19.7ft) deep	Bored Well with Concrete Casing ≤ 6 m (19.7ft) deep	Dug (or Excavated) Well
Annular Seal Material around Casing from ≥ 2.5 m (8.2ft) below Ground Surface to Ground Surface	• Bentonite granules, pellets or chips that have been screened to manufacturer's specifications and have a diameter range between 6 to 20 mm (0.23 to 0.8 inch) are placed immediately above the suitable sealant	• Bentonite granules, pellets or chips that have been screened to manufacturer's specifications and have a diameter range between 6 to 20 mm (0.23 to 0.8 inch) are placed immediately above the suitable sealant	• Suitable sealant that has structural strength to support weight of persons and vehicles
Where Cement is Used in Suitable Sealant Mixture	• Allow cement to cure to manufacturer's specifications or for 12 hours whichever is longer. If cement mixture settles, the suitable sealant shall be topped up to the original level	• Allow cement to cure to manufacturer's specifications or for 12 hours whichever is longer. If cement mixture settles, the suitable sealant shall be topped up to the original level	• Allow cement to cure to manufacturer's specifications or for 12 hours whichever is longer. If cement mixture settles, the suitable sealant shall be topped up to the original level

Reminder: When mixing, handling or placing any grout material (wet and dry), it is important to always follow manufacturer's specifications and recommended procedures. It is also important to consult the Material Safety Data Sheet (MSDS) for additional information on safe handling and usage.

Tremie Pipe
: is a pipe or tube with an inner diameter that is at least three times the diameter of the largest particle of material to pass through it and that is used to conduct material to the bottom of a hole, including a hole containing standing water. For clarification with respect to a tremie pipe, a pipe or tube means a long, hollow (empty space) cylinder.

Well Record - Relevant Sections

Figure 6-1: Well Record - Relevant Sections - Annular Space

Annular Space

- Depth set at (m/ft) From
- Depth set at (m/ft) To
- Type of Sealant Used (Material and Type)
- Volume placed (m^3/ft^3)

Notes:

- Record 'Depth Set at' relative to the ground surface
- Record 'Depth Set at' and 'Volume Placed' in the measurement units indicated at the top of the well record (metric or Imperial)
- Calculate 'Volume Placed' using the information found in "Calculating Amount of Materials Required" in this chapter.

Figure 6-2: Well Record - Relevant Sections - Construction Record

Figure 6-2 shows where the details regarding the construction of the hole and casing the well are to be recorded on the well record.

Construction Record

- Casing
  - Inside Diameter (cm/in)
  - Open Hole or Material (Galvanized, Fibreglass, Concrete, Plastic, Steel)
  - Wall Thickness (cm/in)
  - Depth (m/ft) From
  - Depth (m/ft) To
- Screen
  - Outside Diameter (cm/in)
  - Material (Galvanized, Plastic, Steel)
  - Slot No.
  - Depth (m/ft) From
  - Depth (m/ft) To

Notes:

- Record the 'Depth' of the well relative to the ground surface
- Record the 'Depth' of the well and 'Wall Thickness' using the measurement units indicated on the top of the record (metric or Imperial)

Hole Diameter

- Depth (m/ft) From
- Depth (m/ft) To
- Diameter (cm/in)

Notes:

- Record the 'Diameter' and 'Depth' of the hole using the measurement units indicated on the top of the record (metric or Imperial)
- Record the 'Depth' of the hole relative to the ground surface

Best Management Practice – Report use of Centralizers

The use of centralizers or breakaway guides and where they are located in the well should be reported on the well record in the "Overburden and Bedrock Materials/Abandonment Sealing Record" section of the Well Record. See Chapter 13: Well Records, Documentation, Reporting & Tagging for the complete well record.

Key Concepts

What To Consider When Sealing The Annular Space

The Annular Space

During construction of a well, an annular space is created when the size of the hole in the ground is larger than the casing and well screen diameter.

Best Management Practice – Annular Space Diameter

An annular space needs to be large enough to ensure sealant will fill and adhere around the entire casing. In most subsurface conditions, the hole diameter should be 102 mm (4 inches) to 203 mm (8 inches) larger than the outer finished casing diameter because it facilitates the use of tremie pipes and the placement of the sealant, and possibly the filter pack, in the annular space.

See Chapter 5: Constructing & Casing the Well for information on creating the hole.

Best Management Practice – Annular Space Depth

A properly sealed annular space running the entire length of the casing stabilizes and improves the overall integrity of the well.

Purpose of the Seal

If a casing is placed into the ground without an annular space, the formation material along the casing becomes loosened and disturbed. The disturbed section along the casing can become a pathway for the migration of contaminants, gas and groundwater.

A properly created and filled annular space around a casing will:

- isolate a discrete zone,
- prevent migration of surface water and other foreign materials into the well and aquifers,
- prevent migration of groundwater or contaminants between water bearing formations and subsurface formations,
- prevent migration of groundwater or contaminants between water bearing formations and the ground surface,
- prevent aquifer depressurization by stopping the upward migration of water along the casing, or
- prevent gas migration.

Examples Of Improperly Sealed Annular Spaces

Figure 6-3: Visible Open Annular Space Adjacent To Drilled Well Casing

Figure 6-3 shows an annular space that goes from ground surface to the bottom of the casing (not shown) and allows for migration of surface water and other foreign materials into the well and aquifer.

Figure 6-4: Visible Open And Large Annular Space Around Drilled Well

In Figure 6-4, the annular space extends from ground surface, through an upper aquifer and to the bottom of the casing (not shown). The annular space allows for migration of surface water and other foreign materials into the well and aquifers. It also allows contaminated groundwater from this upper aquifer to mix with and impair the waters of a lower aquifer. In this case, the open space also creates a physical hazard.

This photograph also shows the use of casings with differing diameters that appear to be improperly joined.

Figure 6-5: Visible Open Annular Space Below Pitless Adapter And Horizontal Waterline To The Bottom Of The Casing

Figure 6-5 shows a visible open space (i.e., annular space) below the pitless adapter and horizontal waterline. The open space extends to the bottom of the casing (not shown in photograph). Above the waterline, the person constructing the well installed a bluish grey coloured bentonite grout in the annular space from above the pitless adapter to the ground surface (see circled area). Thus, no one knew the annular space was improperly filled (or left open) below the pitless adapter until the exterior of the well was excavated. The open space acts as a direct pathway for foreign materials to enter and impair groundwater resources.

Annular Space Sealing Exemptions And Special Cases

The *Ontario Water Resources Act* prohibits any person from impairing the quality of any waters in Ontario. This section describes regulatory exemptions to the annular space sealing requirements listed in Table 6-1A and Table 6-1B.

These annular space sealing exemptions do not release anyone from complying with the *Ontario Water Resources Act* general provision regarding the impairment of waters.

The exemption discussed in this section deals with a new well completed with a permanent outer casing - double walled casing.

New Well Completed With A Permanent Outer Casing - Double Walled Casing

In some cases, multiple casings of different diameters are installed in new wells to reach a groundwater zone. This type of installation is common in flowing wells and municipal wells. The annular space around and between the inner casing(s) and the permanent outer casing for a new well must be sealed as follows:

- All construction and sealing requirements for the corresponding well construction method in Table 6-1A and Table 6-1B apply with necessary modifications to the well's annular space on the outside of the outer casing. As a necessary modification, the depth of the annular space must extend from the ground surface to at least the bottom of the permanent outer casing or 6 m (19.7ft), whichever is less.
- If any groundwater is entering the annular space between the inner casing(s) and the permanent outer casing, the entire annular space between the casings must be sealed, with necessary modifications, in accordance to the minimum requirements of Table 6-1A and Table 6-1B. This requirement does not apply to a well pit or to a well constructed by the use of a driven point.
- In all cases, the annular space between casings of different diameters must be sealed with suitable sealant to prevent the entry of surface water and other foreign materials into the well.

Although the person constructing a well is not specifically required to seal the casing below the permanent outer casing; the person must do what is necessary as the *Ontario Water Resources Act* prohibits every person from discharging or causing or permitting the discharge of any material of any kind into any waters that may impair the quality of any waters. This includes prohibiting contaminated groundwater from impairing the quality of other groundwater zones when constructing a well.

Persons using the above professional judgement and the well owner should be aware of the following requirement.

The *Wells Regulation* - If a well acts as a pathway for the movement of:

- natural gas,
- contaminants, or
- other material

  between subsurface formations (including aquifers) or between the ground surface and a subsurface formation and where the movement may impair the quality of any waters, the person abandoning the well, often the well owner, must do one of the following:

- take measures to prevent the movement and ensure the measures are functional at all times, or
- immediately abandon the well .

Reminder: See Chapter 14: Abandonment: When to Plug & Seal Wells and Chapter 15: Abandonment: How to Plug & Seal Wells of this manual for further information on well abandonment.

Requirements For Sealing Various Types Of Wells

Figure 6-6 to Figure 6-13 show cross-sectional illustrations and relevant graphics for the construction of various new wells. The figures show the *Wells Regulation* requirements for minimum hole size, annular space filling products around well screens and suitable sealant in the annular space around the casings.

Reminder: All figures and diagrams are for illustrative purposes only and do not necessarily represent full compliance with other requirements found in the *Wells Regulation* (e.g., well covering during construction).

Reminder: During and after construction the person constructing the well must ensure surface drainage is such that water will not collect or pond in the vicinity of the well.

Reminder: The person constructing the well must also cover the upper open end of the well securely to prevent entry of surface water and other foreign materials into the well during well construction.

Reminder: For details on the hole, casing and other construction requirements not shown in Figure 6-6 to Figure 6-13, refer to the following chapters in this manual:

- Chapter 5: Constructing & Casing the Well
- Chapter 7: Completing the Well's Structure

Reminder: Each of the wells shown in Figure 6-6 to Figure 6-13 may encounter conditions that may require specialized design or construction. For example:

- flowing artesian conditions, presence of gas, or
- breathing (sucking and blowing) conditions where the well and aquifer formation are significantly affected by changes in atmospheric pressure.

Therefore the illustrations and graphics may not depict every circumstance.

Figure 6-6: Drilled Well In Overburden - Well Screens That Are Artificially Packed Or Naturally Developed

The left side of Figure 6-6 shows a cross-sectional diagram of a drilled well in overburden with a well screen. The bottom of the well is completed with a well screen that is located in a water bearing sand and gravel overburden. A plug is located on the bottom of the well screen. The well screen is attached to the casing. The casing extends vertically from the top of the well screen (the water intake zone) to above the ground surface. There is text adjacent to the casing in the diagram. The text indicates that the casing is required to extend from the ground surface to at least 6 metres (19.7 feet) below the ground surface. The top of the casing is capped with a vermin proof well cap and a well tag is affixed to the outside of the casing above the ground surface. The annular space around the casing is filled with suitable sealant and the annular space around the well screen is filled with cleaned wash sand or gravel. It is a requirement that the clean washed sand and gravel can be no closer than 6 metres (19.7 feet) to the ground surface. The ground surface adjacent to the casing is mounded to prevent the ponding of water in the vicinity of the well.

There is a circle drawn around the bottom of the well that includes the well screen, the overburden near the well screen and the casing just above the well screen. There is text that states “see exploded views A, B and C” with an arrow pointing from the text to the circle.

The right side of Figure 6-6 shows three exploded views (A, B and C).

Exploded View A shows a cross-sectional diagram of a well screen installed using an artificial sand or gravel pack. The diagram shows the bottom of a well completed with a well screen that is located in the natural water bearing sand and gravel overburden. A plug is located on the bottom of the well screen. The well screen is attached to the bottom of the casing. The annular space around the outside of the casing is filled with suitable sealant. The annular space around the outside of the well screen is filled with cleaned wash sand or gravel.

Exploded View B shows a cross-sectional diagram of a well screen installed using natural development. The diagram shows the bottom of a well completed with a well screen that is located in the natural water bearing sand and gravel overburden. A plug is located on the bottom of the well screen. The well screen is attached to the bottom of the casing. The annular space around the outside of the casing is filled with suitable sealant. The overburden has collapsed around the outside of the well screen. The overburden around the well screen is developed to remove fine subsurface material and allow groundwater to enter the well through the well screen.

Exploded View C shows a cross-sectional diagram of a well screen installed using natural development and a shale trap. The diagram shows the bottom of the well completed with a well screen that is located in the natural water bearing sand and gravel overburden. A plug is located on the bottom of the well screen. The well screen is attached to the casing. A shale trap is located around the outside the bottom of the casing. There is an annular space around the outside of the casing and immediately above the shale trap. The annular space around the outside of the casing above the shale trap is filled with suitable sealant. The overburden has collapsed around the outside of the well screen. The overburden around the well screen is developed to remove fine subsurface material and allow groundwater to enter the well through the well screen.

- The hole diameter must be at least 7.6 cm (3 inches) greater than the final outer casing (see A or B) for at least 6 m (19.7ft) from the ground surface or the full depth of the well (which is less).
- If centralizers are used with rotary equipment or a breakaway guide is used with cable tool equipment the hole diameter must be at least 5.1 cm (2 inches) greater than the final outer casing (see C) for at least 6 m (19.7ft) from the ground surface or the full depth of the well (whichever is less).
- When the only useful aquifer necessitates a shallower well, the sand or gravel must not be closer than 2.5 m to the ground surface.
- This applies to all wells other than wells contructed by the use of a driven or jetted point, dug wells and bored wells with concrete casing. This will apply to bored wells with casing other than concrete (e.g. galvanized or fiberglass).

Reminder: See the “Filter Packs around Well Screens for Drilled Wells” section in Chapter 5: Constructing the Hole, Casing & Covering the Well for filter pack material information and best management practices about filter packs.

Reminder: If centralizers are used with rotary equipment or a breakaway guide is used with cable tool equipment, the hole diameter must be at least 5.1 cm (2 inches) greater than the final outer casing for at least 6 m (19.7ft) from the ground surface or the full depth of the well (whichever is less). For additional information, see the “Centering the Casing” section in Chapter 5: Constructing the Hole, Casing & Covering the Well.

Reminder: This figure is not to scale, it is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with other requirements found in the *Wells Regulation*.

Figure 6-7: Drilled Well - Without Well Screen

The left side of Figure 6-7 shows a cross-sectional diagram of a drilled well in overburden without using a well screen.

The diagram shows a well completed into gravel overburden. The well is completed with a casing that extends vertically through overburden into a gravel unit. The casing extends from the water intake zone to above the ground surface. There is text adjacent to the casing on the diagram. The text indicates that the casing is required to extend from the ground surface to at least 6 metres (19.7 feet) below the ground surface. A vermin proof well cap is located at the top of the casing and a well tag is affixed to the outside of the casing above the ground surface. The annular space around the outside of the casing is filled with suitable sealant from the ground surface to the top of the gravel. The ground surface adjacent to the casing is mounded to prevent the ponding of water in the vicinity of the well.

There is a circle drawn around the bottom of the well that includes the bottom of the casing and the overburden near the casing on diagram on the left side of Figure 6-7. There is text that states "see exploded views A and B" with an arrow from the text to the circle.

The two exploded views (A and B) are located on the right side of Figure 6-7.

Exploded View A shows a cross-sectional diagram of the bottom portion of the casing driven into an aquifer. The diagram shows the bottom of the well completed with a casing. The bottom of the casing is installed into the water bearing gravel overburden. The annular space located around the outside of the casing above the gravel unit is filled with suitable sealant.

Exploded View B shows a cross-sectional diagram of the bottom portion of the casing driven into an aquifer and a shale trap attached. The diagram shows the bottom of the well completed with a casing. The bottom of the casing is open to the formation. The bottom of the casing is installed into the water bearing gravel unit. A shale trap is located around the outside of the casing and close to the bottom of the casing. The annular space around the outside of the casing and immediately above the shale trap is filled with suitable sealant.

- The hole diameter must be at least 7.6 cm (3 inches) greater than the final outer casing for at least 6 m (19.7ft) from the ground surface or the full depth of the well (whichever is less).
- If centralizers are used with rotary equipment or a breakaway guide is used with cable tool equipment the hole diametermust be at least 5.1 cm (2 inches) greater than the final outer casing for at least 6 m(19.7ft) from the ground surface or the full depth of the well (whichever is less).
- This applies to all wells other than wells constructed by the use of a driven or hetted point, dug wells and bored wells with concrete. This will apply to bored wells with casing other than concrete (e.g. galvanized or fiberglass).
- In this example, the casing has been driven below the bottom of the annular space.

Reminder: If centralizers are used with rotary equipment or a breakaway guide is used with cable tool equipment, the hole diameter must be at least 5.1 cm (2 inches) greater than the final outer casing for at least 6 m (19.7ft) from the ground surface or the full depth of the well (whichever is less). For additional information, see the "Centering the Casing" section in Chapter 5: Constructing the Hole, Casing & Covering the Well.

Reminder: This figure is not to scale, it is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with other requirements found in the *Wells Regulation*.

Figure 6-8: Examples Of Drilled Wells In Bedrock

Figure 6-8 shows a cross-sectional diagram of three wells (A, B and C) completed in bedrock. The three wells are completed through a layer of overburden underlain by weathered bedrock. The weathered bedrock is underlain by solid (or consolidated) bedrock.

The well on the left of the diagram is example "A". The well is completed with a casing that extends vertically from above the ground surface through overburden to the top solid bedrock. The bottom of the casing is sealed into the bedrock immediately below the weathered bedrock to prevent impairment of the well water quality in the bedrock. The well is drilled into the solid bedrock as an open hole as the bedrock has enough strength to not collapse into the hole. The well has a vermin proof well cap and has a well tag affixed to the outside of the casing above the ground surface. The ground surface adjacent to the casing is mounded to prevent the ponding of water in the vicinity of the well.

There is an annular space around the outside of the casing from the ground surface to an elevation in the overburden above the top of the weathered bedrock and this annular space is filled with suitable sealant.

The well in the middle of the diagram is example "B" and is considered "better" than example "A". The well is completed with a casing that extends vertically from above the ground surface through overburden to the top bedrock. A drive shoe (thicker piece of casing) is attached to the bottom of the casing string. The bottom of the casing, with the drive shoe, is sealed and seated at the top of the bedrock immediately below the weathered bedrock. The well is drilled into the solid bedrock as an open hole as the bedrock has enough strength to not collapse into the hole. A vermin proof well cap is located at the top of the casing and a well tag is affixed to the outside of the casing above the ground surface. The ground surface adjacent to the casing is mounded to prevent the ponding of water in the vicinity of the well.

The annular space extending from the ground surface to the weathered bedrock is sealed with a suitable sealant.

The well on the right side of the diagram is example "C" and is considered the "best" of examples "A", "B" and "C". The well is completed with a casing that extends vertically from above the ground surface through overburden to and into the solid bedrock. A drive shoe (thicker piece of casing) is attached to the bottom of the casing string. The bottom of the casing, with the drive shoe, is sealed and seated below the top of the solid bedrock. Below the casing, the well is drilled into the solid bedrock as an open hole as the bedrock has enough strength to not collapse into the hole. A vermin proof well cap is located at the top of the casing and a well tag is affixed to the casing above the ground surface. The ground surface adjacent to the casing is mounded to prevent the ponding of water in the vicinity of the well.

The annular space extending from the ground surface to within the solid bedrock, to the bottom of the driveshoe, is sealed with a suitable sealant.

- The hole diameter must be at least 7.6 cm (3 inches) greater than the final outer casing for at least 6 m (19.7ft) from the ground surface or the full depth of the well (whichever is less).
- If centralizers are used with rotary equipment or a breakaway guide is used with cable tool equipment the hole diameter must be at least 5.1 cm (2 inches) greater than the final outer casing for at least 6 m (19.7ft) from the ground surface or the full depth of the well (whichever is less).
- In this example, the casing in A has been driven below the bottom of the annular space so further annular space is created.

Reminder: If centralizers are used with rotary equipment or a breakaway guide is used with cable tool equipment, the hole diameter must be at least 5.1 cm (2 inches) greater than the final outer casing for at least 6 m (19.7ft) from the ground surface or the full depth of the well (whichever is less). For additional information, see the "Centering the Casing" section in Chapter 5: Constructing the Hole, Casing & Covering the Well.

Reminder: This figure is not to scale, it is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with other requirements found in the *Wells Regulation*.

Figure 6-9: Drilled Well In Overburden-Natural Development, Casing Pulled Back Exposing Screen Method

Figure 6-9 shows a cross-sectional diagram of a drilled well in the overburden using natural development, casing pulled back method.

The diagram shows a hole extending vertically into an overburden subsurface. A casing extends from above the ground surface into the hole. The annular space between the outside of the casing and the side of the hole is filled with suitable sealant. A well screen is shown within the bottom of the casing and extends out of the bottom of the casing into the bottom of the hole in the subsurface. The well screen is located in a water bearing sand and gravel. The well screen is made up of a K-packer, riser pipe, screen, coupling and plug. The K-packer is located at the top of the well screen and seals the inner casing and to the outside of the well screen. The riser pipe extends from the K-packer to below the bottom of the casing in the subsurface. The screen is located below the riser pipe in the subsurface. The coupling and plug are located below the screen.

- The hole diameter must be at least 7.6 cm (3 inches) greater than the final outer casing for at least 6 m (19.7ft) from the ground surface or the full depth of the well (whichever is less).
- If centralizers are used rotary equipment or a breakaway guide is used with cable tool equipment the hole diameter must be at least 5.1 cm (2 inches) greater than the final outer casing for at least 6 m (19.7ft) from the ground surface or the full depth of the well (whichever is less)

Reminder: See the "Filter Packs around Well Screens for Drilled Wells" section in Chapter 5: Constructing the Hole, Casing & Covering the Well for filter pack material information and best management practices about filter packs.

Reminder: If centralizers are used with rotary equipment or a breakaway guide is used with cable tool equipment, the hole diameter must be at least 5.1 cm (2 inches) greater than the final outer casing for at least 6 m (19.7ft) from the ground surface or the full depth of the well (whichever is less). For additional information, see the "Centering the Casing" section in Chapter 5: Constructing the Hole, Casing & Covering the Well.

Reminder: This figure is not to scale, it is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with other requirements found in the *Wells Regulation*.

Figure 6-10: Bored Well With Concrete Casing

Figure 6-10 shows a cross-sectional diagram of a bored well with concrete casing completed into overburden.

The bored well consists of concrete tiles, arranged vertically on top of one another, from above the ground surface into an aquifer in the overburden. The joints and seams in the concrete tiles are required to be permanently watertight to the water intake zone. These concrete tiles with sealed joints are considered casing. The diagram shows two concrete tiles in the water intake zone that are unsealed. There is text adjacent to the casing on the diagram. The text indicates that the casing is required to extend from the ground surface to at least 6 metres (19.7 feet) below the ground surface. If the well extends into the bedrock, the casing is required to extend to the competent bedrock surface. A well cover is located at the top of the casing and a well tag is affixed to the outside of the casing above the ground surface. The ground surface adjacent to the casing is mounded to prevent the ponding of water in the vicinity of the well.

There is an annular space around the concrete tiles. In the water intake zone, the annular space is filled with cleaned, washed, sand or gravel. From the water intake zone to 2.5 metres (8.2 feet) below the ground surface, the annular space is filled with suitable sealant. From the ground surface to 2.5 metres (8.2 metres) below the ground surface, the annular space is filled with bentonite granules, pellets or chips. There is an annular space around the well screen that is filled with cleaned wash sand or gravel. The clean washed sand and gravel can be no closer than 6 metres (19.7 feet) to the ground surface.

- All concrete tiles with joints that are not sealed with mastic are considered a well screen (water intake zone).
- The hole diameter must be at least 15.2 cm (6 inches) greater than the casing's outer diameter from the land surface to a depth of 2.5 m (8.2 ft).
- The hole diameter must be at least 7.6 cm (3 inches) greater than casing's outer diameter from 2.5 m (8.2 ft) to at least 6 m (20ft) below the land surface.
- Sand or gravel must be installed from at least the top of the water intake zone or screen to no closer than 6 m (20ft) below the land surface unless the only useful aquifer available necessitates a shallower well in which case clean, washed sand or gravel must be installed no closer than 2.5 m (8.2 ft) from the land surface.

Reminder: See “Well Screens Using Large Diameter Concrete Tiles” section in Chapter 5: Constructing the Hole, Casing & Covering the Well for information and best management practices on using concrete tiles as well screens.

Reminder: See the “Filter Packs around Well Screens for Drilled Wells” section in Chapter 5: Constructing the Hole, Casing & Covering the Well for filter pack material information and best management practices about filter packs.

Reminder: This figure is not to scale, it is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with other requirements found in the *Wells Regulation*.

Figure 6-11: Dug Well

Figure 6-11 shows a cross-sectional diagram of dug well.

The diagram shows a dug well completed into overburden. The well consists of casing that extends vertically from above the ground surface to below the water table in the overburden. The joints and seams in the casing are required to be permanently watertight to the water intake zone. The diagram shows an unsealed joint between two pieces of casing in the water intake zone. The bottom of the casing is open to the formation. There is text adjacent to the casing on the diagram. The text indicates that the casing is required to extend from the ground surface to at least 6 metres (19.7 feet) below the ground surface. The text also indicates that if the well extends into the bedrock, the casing is required to extend to the competent bedrock surface. A well cover is located at the top of the casing and a well tag is affixed to the outside of the casing above the ground surface. The ground surface adjacent to the casing is mounded to prevent the ponding of water in the vicinity of the well.

The area below the casing is filled with clean, washed sand or gravel. There is an annular space around the outside of the casing. The annular space from the bottom of the casing to 2.5 metres (8.2 feet) below the ground surface is filled with clean, washed sand or gravel. From the ground surface to 2.5 metres (8.2 feet) below the ground surface, the annular space is filled with suitable sealant.

- All concrete tiles with joints that are not sealed are considered well screens (water intake zone).
- Sand or gravel can be replaced with native material (soil) that was excavated from the hole, of the well is not constructed in a contaminated area and the horizons of soil are excavated separately, stored separately, kept free from contamination and backfilled in the same relative positions that they originally occupied.
- Suitable sealant that is used to fill annular space must provide appropriate structural strength to support the weight of persons and vehicles that may move over the well area after it is filled.

Reminder: See “Well Screens Using Large Diameter Concrete Tiles” section in Chapter 5: Constructing & Casing the Well for information and best management practices on using concrete tiles as well screens.

Reminder: This figure is not to scale, it is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with other requirements found in the *Wells Regulation*.

Figure 6-12: Driven Point Well

Figure 6-12 shows a cross-sectional diagram of driven-point well.

The diagram shows a driven-point well completed into into an overburden aquifer. The well consists of casing that extends vertically from above the ground surface to into the water table. A well screen is attached to the bottom of the casing and a drive-point is attached to the bottom of the well screen. Below the frost line in the subsurface a horizontal water line connects to the casing. An excavation zone, created to connect the horizontal waterline to the casing, is filled with suitable sealant from the casing to at least 20 centimetres (8 inches) from the casing and from the bottom of the excavation to at least 20 centimetres (8 inches) from the ground surface. An airtight, well cap is located at the top of the casing and a well tag is affixed to the outside of the casing above the ground surface. The ground surface adjacent to the casing is mounded to prevent the ponding of water in the vicinity of the well.

- The excavation has been created as a result of installing pumping equipment. To see how this is filled see Chapter 9: Equipment Installation, for further instructions.
- If any annular space is created during the driving of the casing, the annular space must be completely filled using materials and a method approved in writing by the Director.

Reminder: The diagram above is not to scale and is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with other requirements found in the *Wells Regulation*.

Figure 6-13: Jetted Well

Figure 6-13 shows a cross-sectional diagram of a jetted point well.

The diagram shows a jetted point well completed into an overburden aquifer. The well consists of casing that extends vertically from above the ground surface to within the water table. A well screen is attached to the bottom of the casing and a drive-point is attached to the bottom of the well screen. An excavation zone, created to connect the horizontal waterline to the casing, is filled with suitable sealant from the casing to at least 20 centimetres (8 inches) from the casing and from the bottom of the excavation to at least 20 centimetres (8 inches) from the ground surface. The annular space located between the casing and the side of the hole extending from the screen to the excavation area is sealed with suitable sealant. An airtight well cap is located at the top of the casing and a well tag is affixed to the casing above the ground surface. The ground surface adjacent to the casing is mounded to prevent the ponding of water in the vicinity of the well.

Below the frost line in the subsurface a horizontal water line connects to the casing.

- The excavation has been created as a result of installing pumping equipment. To see how this is filled see Chapter 9: Equipment Installation, for further instructions.
- A person constructing a well by jetting typically creates an annular space around the well casing. The person constructing a well by jetting must ensure that any annular space around a well casing is sealed to prevent any movement of water, natural gas, contaminants, or other material between subsurface formations (aquifers) or between a subsurface formation and the ground surface.

Reminder: The diagram above is not to scale and is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with other requirements found in the *Wells Regulation*.

Comparision Of Bentonite And Cement Grouts

The most common sealing materials used to seal annular spaces are bentonite and neat cement products. Each have specific, unique and desirable properties. Table 6-2 summarizes the advantages, disadvantages and application of bentonite based sealants (grouts) versus cement based sealants (grouts).

Table 6-2: Some General Bentonite and Cement Advantages and Disadvantages [1]

Sealant	Advantages	Disadvantages

<table>
<tr><th>Sealant</th><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td>Bentonite Based Sealants</td><td>Suitable low permeability with high solids by weight grouts.
Generally non-shrinking and self-healing.
No heat generated during hydration.
Low density.
Sodium bentonite products expand to about 12 to 15 times their original dry volume requiring less material.
Short curing time required before proceeding with further well drilling. To achieve full gel strength bentonite takes 8 to 48 hours.
Properties such as density can be altered with additives.</td><td>Mineralized groundwater (e.g., ≥ 5,000 mg/L of total dissolved solids or ≥ 8,000 mg/L chlorides) will inhibit the hydration process and its effectiveness as a sealant. This includes source water used in mixing bentonite for a grout.
Groundwater characteristics, such as excess hardness (i.e., ≥ 500ppm total hardness) or chlorides (i.e., ≥ 1500ppm) may make bentonite an inappropriate choice as a sealant for the environment as it may not set properly. [2]
Flowing well environments will likely diminish bentonite’s effectiveness
When filling the annular space, bentonite grouts can leak out into open fractures in bedrock environments.
May have an impact on the groundwater chemistry and the well components because it can trade off cations such as sodium, aluminium, iron and manganese.
Additives that may be added to the bentonite slurry (organic and inorganic polymers) may affect groundwater chemistry near the well
Bentonite slurry can make its way through filter packs and screens into the well and into water samples. Thus, it should be placed no closer than 0.9 m (3 ft) to 1.5 m (5ft) above the top of a well screen.
High solids bentonite are not suitable for use at surface in arid climates due to potential for dehydration causing cracking and thus will not perform as a long term effective sealant.
For some grout mixtures with significantly high bentonite solids content (≥ 35%), rapid swelling rate and high viscosity result in difficult pumping through grout pumps and tremie pipes.</td></tr>
</table>

Sealant	Advantages	Disadvantages
Cement Based Sealants	• Suitable low permeability. • Easily mixed and pumped. • Hard-positive seal provides structural integrity (good gel strength) and will not erode or wash-out with water movement. • Supports and adheres to casing. • Any remaining casing is rendered permanent and immovable. • Adheres well to bedrock. • Properties can be altered with additives to reduce hydration time (calcium chloride), to make it stronger (aluminum powder), or have a higher resistance to sulphate rich environments (fly ash). • Expanding cements, Types K, M and S, have characteristics and shrinkage-compensating additives that work well as annular seals • Air-entrained cements work well in cold weather climates because cement with air-entraining agents has water tightness and freeze thaw resistance. • Provides weight and strength to overcome pressures associated with flowing wells.	• Possible shrinkage if extra water is used, if improper additives are used or if the person is not using shrinkage compensated cements. • Settling problems occur if not properly mixed or placed. • Long curing time (minimum 12 hours) increases time to complete well and install equipment in well. • Produces high heat levels during hydration process that can distort some plastic casings. The high heat of hydration in combination with weight of grout also increases the potential for plastic casing to distort or collapse. • High density results in loss of grout to some overburden and bedrock formations. • If prompt equipment cleanup does not occur, solidified cement may result in equipment damage. • In order to properly set, mixing water needs to be cool, clean, fresh water free of oil soluble chemicals, organic material, alkalies, sulphates and other contaminants. • In order to properly set, mixing water needs to have a total dissolved solids concentration of less than 500 mg/L. • Using water that has a high pH may increase setting time. • Equipment such as a tremie pipe needs to be kept cool to prevent flash set problems to pumps and tremie pipes. • If too much water is used in the mixture, the extra water cannot chemically bind with cement (called bleed water), becomes highly alkaline and then can percolate through cement, bentonite and filter pack material causing contamination in groundwater. Voids in the cement created by this bleed water can also be subject to chemical attack and thus, will not perform as a long term effective sealing material. • Prolonged mixing can interrupt heat of hydration process and reduce strength and cement quality. • Neat cement mixtures increase the pH in the subsurface formations. An increase in pH can cause dissolved metals to precipitate from solution onto well components like the well screen, and can cause a negative bias in groundwater sample analyses compared to actual ambient groundwater concentrations. • Weight of cement may increase hydraulic pressure on filter pack and thus compromise and permanently plug the pack material and well screen. • Too thin of a cement mixture may also allow cement to penetrate, compromise and permanently plug the pack material and well screen.

Notes Regarding Table 6-2

Reminder: Suitable sealant must be compatible with the quality of the water in the well.

Reminder: Sealant must be a bentonite mixture of clean water and at least 20% solids by weight, or a product that will be equivalent with respect to the ability to form a permanent watertight barrier. For example, a mixture of water with cement, concrete or cement with no more than 5% bentonite solids by weight may be an equivalent sealant in some environments.

Reminder: When evaluating bentonite as an annular sealant, consider the following:

- The position of the static water level and its seasonal fluctuations
- The ambient groundwater and mixing water quality

Reminder: In some cases 3 to 8% of bentonite is used as an additive to cement or concrete to improve the workability, slurry weight and density of the cement slurry. This may make it easier to pump or pour the material down a narrow tremie pipe or space. However, bentonite is chemically incompatible with cement and will not swell when mixed with cement. The bentonite additive also reduces the set strength of the seal and lengthens set time [3] .

Definitions for sealant, bentonite, watertight, tremie pipe and other relevant terms are provided in Chapter 2: Definitions & Clarifications.

Dry Bentonite Products

Bentonite is manufactured in various forms such as powder, granules, pellets and chips. In some cases, bentonite granules, pellets or chips can be used as a suitable sealant to fill the well's annular space. See the "Grout Placement – Pouring Bentonite Chips and Pellets from Surface" section in this chapter for further information on the placement of dry bentonite into a well's annular space. Table 6-3 provides information on the forms of manufactured bentonite.

Table 6-3: Bentonite Grout Products

Product	Description	Typical Size	Hydration Characteristics
Powder	• Pulverized sodium montmorillonite clay	• Passes 200 mesh	• Mixed with water to form a grout that quickly hydrates • Should not be poured or dropped dry through a column of standing water
Granules	• Irregularly shaped sodium montmorillonite clay particles • Angular to sub-angular	• 1.6 mm to 6 mm (1⁄16 to ¼ inch)	• Hydrates slower than powder but faster than pellets • Should not be poured or dropped dry through a column of standing water • Has a tendency to bridge
Pellets	• Uniformly shaped and sized compressed sodium montmorillonite clay particles • Can be coated with a food-grade wax to slow hydration	• 6 mm to 19 mm (¼ to ¾ inch)	• Hydrates slower than granules but faster than chips. • Coated pellets hydrate slowly and therefore, can be poured or dropped dry through a column of standing water up to 46 m (150ft)
Chips	• Irregularly shaped chunks of sodium montmorillonite clay	• 6 mm to 19 mm (¼ to ¾ inch)	• Due to high moisture content, chips hydrate slowly. • Chips can be poured or dropped dry through a column of standing water up to 152 m (500ft)

Reminder: Some literature indicates that coated bentonite pellets hydrate more slowly than bentonite chips. Other literature indicates that bentonite chips hydrate more slowly than coated bentonite pellets. A person using a bentonite product should always follow the manufacturer's specifications for the use and placement of the bentonite product.

Calculating Amount Of Materials Required

Before beginning well construction, the amount of materials (sand, gravel and bentonite and/or cement) required to properly seal the annular space should be calculated. Regardless of the base materials or type of grout, it is the measured amount of water and the consistent use of that ratio of water to the dry product that is the key element to achieving the appropriate grout properties.

The amount of material needed will depend on the volume of annular space that needs to be filled (i.e., width of the annular space and depth of the annular space).

Some things to remember when calculating the amount of materials required:

- The person constructing the well should allow for possible hole increases due to drilling actions, geology and flushing media. Adding 10% to 15% more material to the calculated amount should be considered.
- The volume of the hole that the casing will occupy should be accounted for.

The following formulae can be used to calculate the volume of the annular space.

Method 1

Annular Space Volume = Volume Of Hole – Volume Of Casing, Where:

Volume Of Hole = $3.14 \times (\text{Diameter Of Hole}/2)^2 \times \text{Depth}$

And

Volume Of Casing = 3.14 × (Outer Diameter Of Casing / 2)^2 × Depth:

Or

Volume Of Hole = 0.785 × Diameter^2 × Depth Of Hole

And

Volume Of Casing = 0.785 × Diameter^2 × Depth Of Hole

Method 2

Where:

D_h
: Diameter of Hole (mm or inches)

d_c
: Outer diameter of casing (e.g. pipe)(mm or inches)

$\{[D_h(mm)^2 - d_c(mm)^2] / 1273\}$ × Depth (metres) = Annular Space Volume (Litres)

Or

$\{[D_h(inches)^2 - d_c(inches)^2] / 29.45\}$ × Depth (feet) = Annular Space Volume (Imperial Gallons)

Reminder: The exact amount of grout (sealant) required cannot always be determined due to irregularities in the size of the hole and losses into fractured rock. Be prepared with extra material onsite to add to the initial estimate if needed.

Reminder: See the "Tools for Annular Space Sealing" section at the end of this chapter for a Grouts (sealants) application matrix to help calculate the amount of grout required to fill the annular space.

The following tables can be used to calculate the volume of sealant (i.e., bentonite, cement, concrete) yielded per bag of product.

Table 6-4: Calculating the Volume of Bentonite at 15%, 20% and 23% Solids Based on One 23 kg (50 lbs) bag of Sodium Bentonite

Volume	15% Solids Grout	20% Solids Grout	23% Solids Grout
Water – Litres	125	91	76
Water – Imperial Gallons	28	20	17
Yield Volume - Litres	133.6	99.6	84.4
Yield Volume – Imperial Gallons	29.4	21.9	18.6

Reminder: The volumes are calculated using the instructions and information on the package or provided by the manufacturer. Different percentages of bentonite slurry are used for various applications when drilling or sealing.

Table 6-5: Calculating the Volume of Concrete and Cement Based on one 43 kg (94 lbs) Bag of Portland Cement

Volume	Concrete	Portland Cement
Water – Litres	19.7	19.7
Water – Imperial Gallons	4.3	4.3
Yield Volume – Litres	60.3	33.3
Yield Volume – Imperial Gallons	13.3	7.3

Reminder: Table 6-5 is based on one, 43 kilogram (94 pound) bag of cement. The volume of concrete is based on one, 43 kilogram (94 pound) bag of cement mixed with 0.027 cubic metres (1 cubic foot) of sand or gravel. The volumes are calculated by using the instructions and information on the package or directly from the manufacturer.

Reminder: One litre of water weighs one kilogram and Portland cement produces a slurry weight of 1.87 kg/L. The volumes are calculated using the instructions and information on the package or provided by the manufacturer.

Mixing Bentonite Grout (Sealant)

When mixing grout, it is important to follow the manufacturer's specifications provided on the packaging or with the product.

Inhibited bentonite grouts (sealants) are a powdered type material that is designed to slow the rate of hydration just long enough to allow the bentonite to be placed into the annular space.

Best Management Practice – Mixing and Placing Bentonite Grout

When mixing bentonite material with clean water, it is important to use a high shear paddle mixer in a mixing drum to thoroughly shear [4] the bentonite particles to suspension. Once properly mixed, the bentonite grout (sealant) is pumped through a tremie pipe to fill the annular space.

Positive displacement pumps with minimal shearing action are needed when placing bentonite grout (sealant) in the annular space. This technique allows for proper placement and hydration of the bentonite grout (sealant) in the annular space.

Techniques For Successful Mixing

To ensure that the bentonite sealant will last the life of the well, bentonite must be mixed with clean water. "Clean," in this context, means water that will not interfere with the reaction to make a bentonite slurry as recommended by the manufacturer and will not impair the water in and around the well.

Best Management Practice – Techniques for Successful Mixing of Bentonite Grout (Sealant)

The following should be considered when mixing bentonite grouts:

- Potable water sources (municipal water, etc.) should not be assumed to be acceptable mixing water for bentonite drilling mud or sealant. Mixing water should always be tested for pH, hardness, total dissolved solids and chlorides before mixing. If available, water quality reports can be reviewed in place of testing the mixing water.
- Bentonite should be mixed with clean water until suspension is achieved. The material should then be immediately pumped into the annular space through a tremie pipe.
- Small batches should be prepared to ensure that at a mixture of least 20% bentonite solids by weight is maintained.
- Gear pumps are better suited for bentonite sealants consisting of bentonite polymer and water mixtures (two step grouts).
- Progressing cavity pumps are better suited for bentonite sealants consisting of bentonite and water mixtures (one step grouts).

Consequences Of Poorly Mixed Bentonite Grout

Mixing water that is not clean (e.g., highly mineralized water), may inhibit the hydration process of the bentonite grout and its effectiveness as a sealant.

If excess "hardness" is present in the mixing water, the polymers and/or bentonite may clump and adhere to the paddles during the mixing phase. In severe cases it can result in plugging of tremie lines and disruption of the grouting process.

Grout that is mixed or sheared too much will start to hydrate too rapidly. This will result in difficulty pumping the grout, plugging up of the tremie line, and wasting a batch.

Reminder: The person constructing the well should follow the manufacturer's specifications for pH, hardness, chloride, total dissolved solids and other water quality issues (see Table 6-2 for further information on water chemistry and its potential effect on bentonite).

Mixing Cement Or Concrete Grout (Sealant)

Cement grout (sealant) must be made using carefully measured quantities of water and Portland cement (see Table 6-4). In concrete grout, aggregate and other materials (e.g., plasticizers) are added to cement and water. Further information on cement can be found at the Portland Cement Association website titled "Cement and Concrete Basics".

A paddle mixer in a mixing drum with either a progressive cavity or gear pump is a common choice for mixing and pumping cement or concrete grout (sealant). Small portable grouting machines that combine both the mixing and the pumping operations are also often used. These machines typically have a positive displacement pump because it can work efficiently against much greater head pressures with low loss of grout volume.

Techniques For Successful Mixing [5]

Best Management Practice – Techniques for Successful Mixing

The following should be considered when mixing cement or concrete grouts:

- The mixing water needs to be cool, clean, fresh water free of oil soluble chemicals, organic material, alkalies and other contaminants and have a total dissolved solids concentration of less than 500 mg/L [6] to ensure proper setting of the grout (sealant).
- It is important that grout be mixed thoroughly and ensure it is free of lumps.
- If the mixture is purchased from a ready-mix concrete plant, the correct proportions of cement, water and other aggregate material, if present, should be verified by using equipment such as a drilling fluid balance.
- It is important to use a protective strainer on the tank from which the grout is pumped into the well's annular space through a tremie pipe.
- The material should be immediately pumped into the annular space through a tremie pipe.

Consequences Of Poorly Mixed Cement Grout

Mixing water that has a high pH or high level of total dissolved solids may result in increased setting times (i.e., slow hydration) and/or failure to set. See Table 6-2 for further information on water chemistry and its potential affect on cement.

If the grout is not thoroughly mixed and free of lumps then partial setting may occur and the effectiveness of the seal will be compromised.

Premature setting may occur due to an incorrect estimate of the hole temperature, the use of hot mixing water, improper water to cement ratios, contaminants in the mixing water, mechanical failures, and interruptions to pumping operations.

Improper water to cement ratios may also cause excessive shrinkage of the grout.

Grout Placement Requirements

The *Wells Regulation* has specific requirements for the placement of materials in the annular space for new wells (see Table 6-1A and Table 6-1B in the "Requirements Plainly Stated" section of this chapter).

The *Wells Regulation* requires that any annular space of any new cased well, other than the annular space surrounding the well screen, must be sealed to prevent any movement of water, natural gas, contaminants or other material between subsurface formations or between subsurface formations and the ground surface by means of the annular space. This requirement does not apply to the annular space around an inner casing where a new well has been constructed with a permanent outer casing (see the "New Well Completed with a Permanent Outer Casing – Double Walled Casing" section of this chapter)

For new cased wells, the *Wells Regulation* requires that

- a tremie pipe be used to install the suitable sealant.
- the bottom of the tremie pipe remain immersed in the rising accumulation of sealant.

This tremie pipe requirement does not apply for new dug wells, wells constructed with the use of a driven point and wells constructed by jetting.

Successful placement of the grout will depend on the temperature, stability, size of the annular space and pressure in the hole, and how well the casing is centered, and the grouting placement. The following best management practice on sealing the annular space provides

suggestions to help achieve a successful seal.

Best Management Practice – Sealing the Annular Space

The following will help ensure that the sealant will provide a satisfactory seal:

- During placement of sealant, the sealant returning to the surface should be of the same consistency of that being pumped.
- The first indication of sealant returning to surface is not an indication to stop pumping.
- Where the tremie pipe is placed in the annular space, active pumping of the sealant should continue as the tremie pipe is extracted from the annular space to ensure effective displacement.
- Sealant pump suction and discharge hoses should be adequately sized to overcome friction losses and decrease chances of plugging.
- Suction and discharge hose connections to the pump should be made using quick-connect style couplings. This will save time when attempting to locate a blockage in the hose and allow faster cleanup.
- When the pump is also used for mixing, the discharge hose should be plumbed in such a manner to allow changeover from mixing to pumping sealant without shutting down the pump.
- A pressure gauge should be installed on the pump discharge and monitored to ensure that the working pressure does not exceed the hose and pipe maximum pressure rating. A sudden increase in pressure may indicate that the tremie pipe has become plugged.

Sealant (Grout) Placement Techniques

The following sections provide different techniques used to place suitable sealant into an annular space.

Grout Placement - Inner String Method

In the inner string method of placing grout, the tremie is suspended in the casing. A cementing (float) shoe is attached to the bottom of the casing before the casing is placed in the hole. The tremie pipe is lowered until it engages the shoe.

Placing Grout Using the Inner String Method

To place grout using the inner string method:

1. A float shoe or other similar device is attached to the bottom of the casing before the casing is placed in the hole.
2. The casing is placed in the hole to the bottom of the well. Then the tremie pipe is lowered inside the casing until it engages the shoe. This permits the grout to pass into the annular space but prevents it from leaking back into the casing while pumping the grout.
3. Water or drilling fluid is placed into the casing to prevent the grout from coming back up the casing.

   Reminder: For shorter strings of casing [i.e., 6 to 30 metres (20ft to 100ft)], the tremie pipe is sealed at the top of the casing using one or two stacked top well seals. The barrier created by the well seals along with the weight of the drilling fluid or water will minimize the amount of grout that can travel back up the inside of the casing string during and after the pumping process.

4. The grout is pumped through the tremie pipe and float shoe and is forced upward around the casing.
5. The tremie pipe is disconnected and removed.
6. All of the grouting equipment is cleaned.
7.
   a. Where bentonite grout is used and before further well construction proceeds, the bentonite should be allowed time to achieve gel strength. Bentonite takes 8 to 48 hours to achieve full gel strength.

      Best Management Practice – Topping Up Settled Bentonite Grout

      The bentonite grout should be topped up to the original level before drilling continues if there has been settling or subsidence in the annular space.

   b. The *Wells Regulation* - Where cement grout is used, cement must be allowed to set according to manufacturer's specifications, or 12 hours, whichever is longer. If there has been settling or subsidence in the annular space, the cement grout must be topped up to the original level before drilling continues.
8. The float shoe or other device is drilled out or removed from the bottom of the casing.

Reminder: The sealant at the bottom of the casing is susceptible to damage when drilling restarts. The sealant must be physically and structurally sound and capable of withstanding the initial pressures of drilling. After the placement of grout, it is important to prevent flushing media from pushing up and exerting pressure on the grout column when drilling resumes. This upward pressure can be caused by the displacement of water in the casing when using the percussion drilling action or when using air or water based flushing media.

Figure 6-14: Pumping Grout Down Tremie Pipe - Inside Casing

Figure 6-14 shows a steel casing extending out of the ground behind a drill rig. A clamp has been placed around the casing and above a wooden stump to hold the casing in place. A hose from a grout pump (not shown) is attached to a tremie line above the well casing and hidden behind a steel plate. A bentonite grout (suitable sealant) is being forced down the tremie pipe inside the well casing. The grout is being pushed out below the casing and is being forced up the annular space. The benontite grout is seen coming out of the annular space onto the ground surface around the casing.

Figure 6-15: Inner String Method Of Grout Placement

Figure 6-15 shows a cross-sectional diagram of the inner string method to place grout (sealant) into a well.

The diagram shows a vertical hole that extends into the subsurface. A suspended casing has been placed into the hole from above the ground surface to just above the bottom of the hole. A float shoe has been installed at the bottom portion of the casing. A tremie pipe is inserted within the casing and through the float shoe. Centralizers have been installed between the outside of the tremie pipe and the inside of the casing.

An annular space is located between the outside of the casing to the side of the hole. Above the ground surface, a horizontal tremie pipe is attached to the vertical tremie pipe. The horizontal tremie pipe is attached to a grout pump. Another horizontal pipe is attached to the grout pump and a vertical pipe. The vertical pipe is attached to a hopper that contains sealant.

There are arrows and small circles in the diagram demonstrating the flow of sealant through the hopper, horizontal tremie pipe, grout pump and vertical tremie pipe and discharging out of the bottom of the tremie pipe into the bottom of the hole. The arrows are also demonstrating the sealant is being forced upward in the annular space from the bottom of the hole to the ground surface.

Reminder: This figure is not to scale, it is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with other requirements found in the *Wells Regulation*.

Grout Placement - Tremie Pipe Outside Casing Method

When using this placement method, the grout material is pumped or placed using a tremie pipe that is installed in the annular space.

Best Management Practice – Use of a Grout Pump

When a grout pump is used with a tremie pipe, any fluid (i.e., drilling mud or water) of less weight than the grout will be displaced from the annular space. This technique assists in the proper filling of any voids or spaces with grout (sealant).

Best Management Practice – Use of a Larger Diameter Tremie Pipe

The use as large a tremie pipe:

- reduces the amount of friction loss that is associated with a small diameter tremie pipe,
- reduces the velocity of grout entering the annular space,
- enhances the efficiency of the displacement process and
- significantly improves the effectiveness of the overall seal.

Reminder: The annular space must meet regulatory requirements (see Table 5-5 of and Table 6-1 of this chapter) and be large enough to accommodate the tremie pipe (see Chapter 5: Constructing the Hole, Casing and Covering the Well; “Best Management Practice: Size of Hole”).

Placing Grout Using the Outside Casing Method

To place grout using the tremie pipe outside the casing:

1. The lower end of the casing is closed with a drillable plug to ensure the grout that is placed in the annular space cannot enter the casing.

   Another option is to drive the casing into the undisturbed formation below the hole.

2. The tremie pipe is installed into the annular space. The person constructing the well must ensure that the tremie pipe reaches the bottom of the annular space.
3. a. If a pump is used, the grout is pumped down the tremie pipe discharging into the bottom annular space. Continued discharge of grout into the bottom of the annular space causes the rising accumulation of grout to reach the ground surface.

      The pump must be capable of developing enough pressure to overcome the friction caused by moving the grout through the tremie pipe and up the annular space.

      Issues with a grout pressure head that may prevent the upward placement of grout with a pump are not usually a concern since the grout that is rising to the ground surface is at or below the grout pump elevation.

      In some circumstances, it may be advisable to pull the tremie pipe at about the same rate that grout is filling the annular space after the first mixed batch of grout is pumped into the annular space. This will minimize the grout pressure head on the tremie pipe outlet and reduce any chances of the tremie pipe being stuck in the hole due to hydration of the grout.

   b. If a pump is not used, the grout is poured down a tremie pipe above the ground surface. The grout flows from the tremie pipe into the bottom annular space by the force of gravity. The tremie pipe is raised slowly and the bottom of the tremie pipe remains in the rising accumulation of the grout until the grout reaches the ground surface.

      The *Wells Regulation* - The bottom of the tremie pipe must remain submerged in the rising accumulation of grout until placement of the grout is complete.

4. Grouting may be complete when the grout leaving the annular space at the ground surface is of the same consistency as the grout being introduced into the bottom of the annular space.
5. The tremie pipe is disconnect and removed.
6. All grouting equipment is cleaned.
7. a. Where bentonite grout is used and before further well construction proceeds, the bentonite should be allowed time to achieve gel strength. Bentonite takes 8 to 48 hours to achieve full gel strength.

      Best Management Practice – Topping up Settled Bentonite Grout

      The bentonite grout should be topped up to the original level before drilling continues if there has been settling or subsidence in the annular space.

   b. Where cement grout is used, cement must be allowed to set according to manufacturer's specifications, or 12 hours, whichever is longer. If there has been settling or subsidence in the annular space, the cement grout must be topped up to the original level before drilling continues.
8. The plug is drilled out or removed from the bottom of the casing.

Reminder: The sealant at the bottom of the casing is susceptible to damage when drilling restarts. The sealant must be physically and structurally sound and capable of withstanding the initial pressures of drilling. After the placement of grout, it is important to prevent flushing media from pushing up and exerting pressure on the grout column when drilling resumes. This upward pressure can be caused by the displacement of water in the casing when using percussion drilling action or when using air or water based flushing media.

Figure 6-16: Outside Casing Method Of Grout Placement

Figure 6-16 shows a cross-sectional diagram of the outside casing method to place grout (sealant) into a well.

The diagram shows a vertical hole that extends into the subsurface. A suspended casing has been placed into the hole from above the ground surface to just above the bottom of the hole. A plug has been placed at the bottom of the casing. An annular space is located from the outside of the casing to the side of the hole. A vertical tremie pipe has been installed inside the annular space, located to the left of the casing, from above the ground surface to the bottom of the casing.

Above the ground surface, a horizontal tremie pipe is attached to the vertical tremie pipe. The horizontal tremie pipe is attached to a grout pump. Another horizontal pipe is attached to the grout pump and a vertical pipe. The vertical pipe is attached to a hopper that contains sealant.

There are arrows and small circles in the diagram demonstrating the flow of sealant through the hopper, horizontal tremie pipe, grout pump and vertical tremie pipe and discharging out of the bottom of the tremie pipe into the bottom of the hole. The arrows are also demonstrating the sealant is being forced upward in the annular space from the bottom of the hole to the ground surface.

Reminder: This figure is not to scale, it is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with other requirements found in the *Wells Regulation*.

Figure 6-17: Installing Tremie Pipe Outside Casing

Figure 6-17 shows a tremie pipe being installed in the annular space of a drilled well. The permanent steel casing is being held in place by the drilling rig. A larger diameter starter (or temporary) casing has been installed during the drilling of the hole. The difference in diameter between the two casings has created an annular space large enough to allow for the placement of the tremie pipe.

Figure 6-18: Tremie Remains In Hole During Grout Placement

Figure 6-18 shows the tremie pipe remaining in the annular space while grout is being pumped through it to fill the entire annular space. In some cases, the tremie pipe may need to be raised during pumping to ensure the tremie pipe does not get stuck in the curing sealant.

Figure 6-19: A Successful Seal

Figure 6-19 shows a suitable sealant that has been placed in the annular space along the casing and up to the ground surface.

Figure 6-20: Example of a Properly Sealed Annular Space

Figure 6-20 shows a hole excavated beside a drilled well. The photograph shows the bluish-grey coloured bentonite grout that has filled the annular space of the drilled well adjacent to the black drilled well casing. The bentonite has also adhered to the sand and gravel overburden. The pop can adjacent to the casing near the bottom of the excavation provides the approximate thickness of the grout.

Figure 6-21: Examples of a Properly Sealed Annular Space - Close Up

Figure 6-21 shows a close-up of the same drilled well. The photograph shows the bluish-grey bentonite grout that has filled the annular space of the well adjacent to the black drilled well casing and which has adhered to the sand and gravel overburden.

Grout Placement - Pouring Without Tremie Pipe

A tremie pipe is not required when filling the annular space of:

- a new dug well,
- the upper 2.5 m (8.2ft) of a new bored well with approved concrete casing, or
- a new well pit.

The *Wells Regulation* - The grout (sealant) must provide appropriate structural strength to support the weight of persons and vehicles that may move over the annular space of a dug well or well pit.

Reminder: Care is needed when filling the annular space around a large diameter casing that is thin-walled (e.g., fiberglass or corrugated steel) to reduce the risk of distorting the casing wall or casing joints. Care is also needed when pouring suitable sealant to ensure that bridging will not occur.

Grout Placement - Pouring Bentonite Chips And Pellets From Surface

A dry, manufactured bentonite product, such as chips and pellets, can be placed into the hole's annular space by a gravity method (i.e., pouring the material from the ground surface) where there is a larger diameter starter (or temporary) casing surrounding a smaller diameter permanent casing. In this case, the starter (or temporary) casing is a pipe that acts as a tremie pipe.

Tremie Pipe

A pipe or tube with an inner diameter that is at least three times the diameter of the largest particle of material to pass through it, and that is used to conduct material to the bottom of a hole, including a hole containing standing water.

In this case, the annular space between the starter casing and permanent outer casing must meet the definition of a tremie pipe for this method to be used.

Upon proper placement of the dry bentonite product into the annular space, the starter (or temporary) casing is removed.

If this method of placement of dry bentonite is used, certain precautions should be taken for the reasons discussed below. When pouring dry bentonite from the surface, there is an increased risk of bridging. A high rate of pouring causes the bentonite to clog at an elevation above the bottom of the annular space. In other cases, the bentonite encounters groundwater and hydrates before it settles to the bottom of the annular space. Open gaps, due to bridging, can allow contaminants to travel vertically in the open portion of the well, destabilize the structure of the well and decrease the effectiveness of the plugging materials.

This method may also lead to uneven hydration of dry bentonite in certain situations. As such, improperly hydrated bentonite may not hold the weight of the well column and may cause serious structural problems with the well.

See the best management practice titled "Taking Precautions when Using and Pouring Dry Bentonite Products" in this chapter.

Best Management Practice – Taking Precautions when Using and Pouring Dry Bentonite Products

If sodium bentonite is used and poured in an annular space from the surface using a starter casing or other tremie pipe, the material should be in a pellet or chip form. The material should be screened and placed in accordance with the manufacturer's specifications.

Precautions when plugging a well with dry bentonite products include the following:

- Installing a considerably larger diameter hole than the casing and the casing has been centered using centralizers.
- Pouring the products at a rate no faster than 3 minutes per 22 kilogram (50 pound) bag.
- Halting the pouring process occasionally and lowering a weighted measuring tape into the well until it reaches the top of the products to confirm that bridging has not occurred.
- Using a tamping device to break any bridges that form.
- Lifting the starter casing as the dry material is added in a manner that keeps the bottom of the tremie pipe immersed in the rising accumulation of dry material, in order to reduce the risk of void spaces between the bentonite and the formation.
- Making sure the bentonite is continually hydrated, where necessary, by periodically adding clean water to the bentonite that has been placed in the well.
- Using a coating on the bentonite that retards swelling for several minutes to allow the bentonite pellets to drop through a shallow water column in the annular space.
- Using slower expanding chips rather than pellets when dropping bentonite through a water column in the annular space.

In situations where there is too much water in the annular space to use a dry bentonite product, a grout mixture and a smaller tremie pipe should be used.

Grout Placement - Displacement Method

The displacement method involves calculating a volume of sealant (grout) material needed to fill the annular space.

Placing Grout Using the Displacement Method

1. In many cases, a starter (or temporary) casing is placed into the hole to support the sides of the well. The sealant is typically installed into the drilled hole by a gravity method such as pouring the material from the ground surface. In this case the starter casing acts as a tremie pipe. In other cases, a tremie pipe is lowered into the open hole and the grout is placed into the open hole through a tremie pipe.

Reminder: For further clarification of the definition of Tremie Pipe see Chapter 2: Definitions and Clarifications, Table 2-1 or the "Grout Placement – Pouring Bentonite Chips and Pellets from Surface" section in this chapter.

2. A well casing with a plug located on the bottom of the casing is installed into the hole. The grout (sealant) is displaced by the casing and pushed up into the annular space.

   Reminder: Plugs should be made of material that is easily drilled through (e.g., wood or cement).

3. If the sealant does not fill the entire annular space beside the well casing, then the sealant must be topped up using a tremie pipe to fill the entire annular space to the ground surface.
4. a. Where bentonite grout is used, and before further well construction proceeds, allow the bentonite time to achieve gel strength. To achieve full gel strength bentonite takes 8 to 48 hours.

   > Best Management Practice – Topping Up Settled Bentonite Grout
   >
   > The bentonite grout should be topped up to the original level before drilling continues if there has been settling or subsidence in the annular space.

   b. Where cement grout is used, cement grout must be allowed to set according to manufacturer's specifications, or 12 hours, whichever is longer. If there has been settling or subsidence in the annular space, the cement grout must be topped up to the original level before drilling continues.
5. The plug is drilled out or removed from the bottom of the casing.

Reminder: The displacement method using a tremie pipe allows the sealant to be continuously deposited into the hole. The casing with plug can then be installed into the well and meets the requirements of the *Wells Regulation*. The volume of sealant placed in the hole must be able to rise from the bottom of the annular space to the ground surface.

Figure 6-22: Grout Displacement Method

Figure 6-22 shows a cross-sectional diagram of the grout displacement method to place grout (sealant) into a well.

The diagram shows a vertical initial outer drill hole that extends into the subsurface. The subsurface consists of an upper layer of top soil underlain by a consolidated bedrock formation.

A suspended casing has been placed into the hole from above the ground surface to about three quarters of the depth of the hole. The bottom of the casing will eventually rest at the bottom of the initial drill hole. A drillable plug has been placed at the bottom of the casing. Centring guides have been placed on the upper and lower portion of the casing. The centring guides extend from the outside of the casing to the side of the hole. An annular space is located from the outside of the casing to the side of the hole. Suitable sealant (grout) has been placed into the hole with a tremie pipe (not shown) below the casing and around the casing from about half of the depth of the hole to the bottom of the hole.

1. Grout measured and placed in hole through a tremie pipe.
2. Well casing with bottom drillable plug and centralizers (centering guides) are placed into the well. The bottom of the well casing is placed at the bottom of the inital drill hole in the well.
3. Well casing filled with water or pressure applied to hold casing in place until suitable sealant (grout) properly sets.

Reminder: This figure is not to scale, it is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with other requirements found in the *Wells Regulation*.

Grout Placement - Double Plug Procedures [7]

The method is more common in the construction of oil and gas wells than water wells. It involves calculating a volume of grout (sealant) material needed to fill the annular space. As this method involves installing the pre-determined batch inside the well casing and pushing it into the annular space from below the well casing, care is needed to determine if the volume of grout (sealant) within the well casing exceeds the volume of the entire annular space.

Reminder: When determining the volume of grout needed, it is important to include an amount of grout that will leave 3 m to 4.6 m (10ft to 15ft) of grout (sealant) in the casing after the annular space has been filled.

Placing Grout Using the Double Plug Method

To place grout using the double plug method:

1. A casing with a plug is installed in the hole. The casing is held above the bottom of the well. A pump and pipe are hooked onto the casing above the ground surface.

   Reminder: Plugs should be made of material that is easily drilled through (e.g., wood or cement).

2. Grout (sealant) is pumped into the casing above the plug. In this case, the casing acts as the tremie pipe.
3. A second plug is installed above the grout. The use of a plug helps ensure slurry and water separation, resulting in a proper grout seal at the lower end of the casing.
4. Clean water or drilling fluid is then pumped into the casing causing the plugs and grout to move down the casing. As the plugs move down the casing, water or drilling fluid inside the casing is displaced. The process allows the lower plug to fall below the bottom of the casing and the grout moves up and into the annular space.
5.
   a. Where bentonite grout is used, and before further well construction proceeds, the bentonite should be allowed time to achieve gel strength. Bentonite takes 8 to 48 hours to achieve full gel strength.

      Best Management Practice – When Bentonite Grout Settles

      If there has been settling or subsidence in the annular space, top up the bentonite grout to the original level before drilling continues

   b. Where cement grout is used, cement grout must be allowed to set according to manufacturer's specifications, or 12 hours, whichever is longer. If there has been settling or subsidence in the annular space, the cement grout must be topped up to the original level before drilling continues.
6. The plugs are drilled out or removed from the bottom of the casing.

Reminder: Landing collars below the lower plug can be used to reduce the potential for over or under displacement of the grout (sealant). Wire lines attached to the upper plug can also be used to assist in accurately measuring depths when the plugs come together and reduce the risk of damage to the well casing.

Grout Placement - Annular Space For Driven Points

Definition - Construction by a driven point means a method of well construction that uses a solid point or cone that is driven into the ground. This does not include a cutting shoe unless a solid point is installed on an inner rod. This method is not machinery specific.

For example, the type of machinery that can be used to drive the solid point or cone into the ground can include direct push technology, rotary, percussion, pneumatic hammers, sonic, non-powered manual methods, and cone penetration testing equipment.

The *Wells Regulation* - If a new well is constructed by the use of a driven point, the person constructing the well must ensure that any annular space created is filled to the ground surface using a material and a method approved in writing by the Director. An application must be made to the Director to obtain the written approval.

The request for an approved material and method to seal the annular space of a driven point well must be made and approved prior to constructing the new well. See the following sections in this chapter for details on the written consent process.

Creating And Sealing Annular Spaces Of Driven Point Wells

The driving action during the installation of a driven point well pushes the formation to the sides of the point well and typically does not create a measurable annular space. However, excavations need to be created to connect the driven point well to the horizontal pipe (waterline). The horizontal pipe connects the driven point well to the building's plumbing. As part of backfilling these excavations, a suitable sealant needs to be placed from the bottom of the trench to within 20 cm (8 inches) of the ground surface. This suitable sealant also needs to be placed from the well casing a minimum distance outward of 20 cm (8 inches) in the excavation. The sealant placed in the horizontal pipe excavation (trench) around the well casing reduces the risk of surface water runoff and other near surface sources of contaminants from migrating down the outside of the well casing and impairing the well water.

Reminder: For further information on backfilling trenches from driven point wells see Chapter 9: Equipment Installation and Figure 6-23 in this chapter.

To ensure that any potential annular space that may be present below the ground surface, or disturbed formation beside the casing, does not act as a pathway for contaminants to enter the water in the well and aquifer, the person constructing a well with the use of a driven point may create an annular space outside of the well casing on purpose. If an annular space is created, the person constructing the well with the use of a driven point must fill the annular space with suitable sealant. If an annular space is created and sealed for a new well

constructed with the use of a driven point, the person constructing the well could follow the "Best Management Practice - A Method of Creating and Sealing Annular Space of a Well Constructed with the Use of a Driven Point" in this chapter. However, the Director must provide a written consent to the person constructing the well before an annular space is created and sealed for a new well constructed with the use of a driven-point.

Reminder: For further information on how the Director's written consent to allow for the creating and sealing of a new well constructed with the use of a driven point see the "Where does the Person Constructing the Well have to go to seek a Written Approval from the Director?" in this chapter.

Best Management Practice – A Method of Creating and Sealing Annular Space of a Well Constructed with the Use of a Driven Point

The person constructing the well with the use of a driven point should do the following:

1. A hole should be excavated below the frost line. This hole is part of a trench that will take the horizontal pipe (waterline) from the driven point well to the building's plumbing.
2. Below the excavated area, a well casing with a driven point (or a dynamic cone) that has an outside diameter of at least 11.75 cm (4 5/8 inches) into the water producing zone should be driven into the ground. The casing can be driven into the ground with machinery such as direct push technology or by manual methods.
3. A driven point well screen and casing that has a diameter of about 6.7 cm (2 5/8 inches) should be placed into the 11.75 cm (4 5/8 inches) diameter casing. The driven point well should be centered in the 11.75 cm (4 5/8 inches) diameter working casing.
4. The 11.75 cm diameter casing is pulled out of the ground leaving the one-time use drive point in the well while doing one of the following:
   a. The annular space around the screen portion of the drive point is filled with a clean sand or gravel. The top of the sand or gravel should come no closer than 6 m (19.7ft) below ground surface or no closer than 2.5 m (8.2ft) below ground if the only useable aquifer necessitates a shallower well. Recognizing there is a potential for the sand or gravel to bridge due to the small diameter of the well and annular space, it is important to calculate the volume of the annular space around the screen and ensure the same volume of sand or gravel materials is placed into the well. Clean sand or gravel will also need to be poured slowly from the top of the annular space to prevent bridging.
   b. The annular space above the sand or gravel is filled by one of the following:
      i. A tremie pipe is placed in the annular space just above the sand or gravel. The casing portion of the well's annular space is filled with suitable sealant from the top of the well screen to the floor of the excavation using the tremie pipe and a grout pump. The suitable sealant will typically consist of at least 20% solids of sodium bentonite by weight.
      ii. Sodium bentonite chips or pellets are placed in the annular space. Recognizing there is a potential for the bentonite chips or pellets to bridge due to the small diameter of the well and annular space, it is important to calculate the volume of the annular space and ensure the same volume of plugging materials are added to the well. Sodium bentonite chips and pellets should also be poured slowly from the top of the annular space to prevent bridging. At different intervals, the sodium bentonite chips or pellets will need to be hydrated with clean and potable water to allow the bentonite to expand in the annular space.
5. The filling of the well in the excavation should be completed as shown in Chapter 9: Equipment Installation.

Reminder: For Steps 2 through 4, in the Best Management Practice above, different diameters of driven point wells can be used, however, it is important that the initial hole be at least 5 cm (2 inches) larger than the outer diameter of the final well casing to prevent bridging problems in the annular space. This Best Management Practice is shown in Figure 6-23 in this chapter.

Figure 6-23: Suggested Method of Creating and Sealing Annular Space in a Driven Point Well

Figure 6-23 shows a cross-sectional diagram of a grout method to creating and sealing an annular space in a driven-point well.

The diagram shows four steps of construction into the subsurface. Near the ground surface, there is a blue dotted horizontal line that represents the frost line.

Step 1 is located on the left side of the diagram. Step 1 shows an excavated hole that extends from the ground surface to below the frost line in the subsurface.

Step 2 shows the same excavated hole as shown in Step 1. Step 2 also shows a vertical temporary (outer) casing that extends from above the ground surface, through the excavated hole and into the subsurface. An expendable driven-point has been placed at the bottom of the temporary (outer) casing.

Step 3 shows the same excavated hole as shown in Step 1. Step 3 also shows the same vertical temporary (outer) casing and expendable driven-point as shown in Step 2. Step 3 shows a permanent (inner) casing within the temporary (outer) casing. The permanent (inner) casing is located from above the ground surface to almost the bottom of the hole created by the temporary (outer) casing and expendable driven-point. A well screen with a driven-point is attached to the bottom of the permanent (inner) casing. The well screen with a driven-point is located within the permanent (outer) casing and expendable driven-point. An annular space has been created between the permanent (inner) casing/well screen and the temporary (outer) casing. Clean sand or gravel has been placed in the annular space from the driven-point to just above the well screen.

Step 4 shows the same excavated hole as shown in Step 1. In addition, Step 4 also shows the same vertical temporary (outer) casing, expendable driven-point, permanent (inner) casing, well screen, inner driven-point and a clean sand or gravel as shown in Step 3. The remaining annular space above the clean sand and gravel has been filled with a suitable sealant. Arrows have been placed on the top of the temporary (outer) casing to represent that the temporary (outer) casing is being pulled out of the ground.

Reminder: Step 4, a T-connection is installed on top of the casing to allow for the horizontal waterline to connect to the well. Additional casing is added on the well from the T-connection to above the ground surface and the trench is backfilled in accordance with the *Wells Regulation* (see Chapter 9: Equipment Installation).
Lining up the two points helps to centre the inner string. The inner driven point, in some cases, may rest on top of the initial point (e.g., if it is solid).

Reminder: The diagram above is not to scale and is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with other requirements found in the *Wells Regulation*.

Where Does the Person Constructing the Well Have to Go to Seek a Written Approval From the Director?

If the person constructing the new well is required to seek the written consent of the Director to use an alternate method to fill the annular space of a well constructed by the use of a driven point, the person may contact the Wells Help Desk:

- In writing to Wells Help Desk, Environmental Monitoring and Reporting Branch of the Ministry of the Environment and Climate Change, 125 Resources Road, Toronto, ON M8P 3V6;
- By fax at: 416-235-5960 or
- By e–mail at helpdesk@waterwellontario.ca

For further information, the person constructing the well can contact the Wells Help Desk by telephone at (for Ontario residents only).

What Information Is Needed For A Written Approval?

The Ministry assesses each case individually and on its merits. As a minimum, applicant's contacting the Ministry for a written approval should provide a written request that includes but is not limited to the following information:

- The name of the individual/entity that owns the well
- The location of the well
- The number of wells
- The purpose and use of the well
- The type of casing and well screen that will be used
- The type of sealant material and method being proposed to fill the annular space
- The reason for the proposed sealant material and methods
- If applicable, written certification by the manufacturer/installer/professional engineer that the material and method will properly fill the annular space
- Details on how the person will verify that the placement of the sealant materials in the annular space is uniform and does not bridge
- Details on any flowing well conditions and how the proposed material and method will prevent the vertical movement of groundwater in the annular space and near the well site
- Details on any identified or expected contaminant or mineralized condition and how the proposed material and method will effectively seal the annular space to the ground surface

- Other potential permits or approvals that are being applied for in relation to the construction or use of the well. For example, the need for a Permit To Take Water if the water from the well is being taken at a rate of more than 50,000 litres one any one day for well development purposes.

The person constructing the well may be required to retain a Professional Engineer or Professional Geoscientist who would have to prepare a scientific report showing the appropriate scientific rationale to support the application. The person constructing the well would have to submit the report along with the request for written approval to the Ministry for its consideration.

The Director has reviewed the "Best Management Practice - A Method of Creating and Sealing Annular Space of a Well Constructed with the Use of a Driven Point" and Figure 6-23 in this chapter

In many environments the Director will likely support a material and method for sealing the annular space that is consistent with the "Best Management Practice - A Method of Creating and Sealing Annular Space of a Well Constructed with the Use of a Driven Point" and Figure 6-23 in this chapter. As such, the person constructing the well is encouraged to review the "Best Management Practice - A Method of Creating and Sealing Annular Space of a Well Constructed with the Use of a Driven Point" and Figure 6-23 in this chapter and should indicate on the application, whether and how the standards listed above will be met.

The request for written approval should be submitted to the Ministry along with any and all supporting documents such as a hydrogeological and/or a well design report.

Depending on the case, and as part of the Director's consideration, the Director may ask other regulators and interested parties to comment on the request.

The person constructing the well and others should be cautioned that obtaining a written consent will not be an automatic process, since the Ministry has to provide for the conservation, protection and management of Ontario's waters and for their efficient and sustainable use, to promote Ontario's long-term environmental, social and economic well being.

Based on the information, the Ministry will contact the well owner in writing indicating the Director's decision.

Tools For Annular Space & Sealing

Table 6-6 provides an example of the types of reference charts and tables that can be used to volumes of holes and casing and determine the approximate amount of suitable sealant needed to fill the annular space.

Table 6-6: Calculating Casing and Hole Volume

Diameter Millimetres	**Diameter Inches**	**Volume m^3/m**	**Volume ft^3/ft**	**Volume US gal/ft**	**Volume Imp gal/ft**
51	2	0.002	0.022	0.161	0.134
64	2½	0.003	0.032	0.241	0.201
76	3	0.005	0.054	0.402	0.335
89	3½	0.006	0.065	0.483	0.402
102	4	0.008	0.086	0.643	0.536
114	4½	0.010	0.108	0.804	0.670
127	5	0.013	0.140	1.046	0.871
140	5½	0.015	0.161	1.206	1.005
152	6	0.018	0.194	1.448	1.206
165	6½	0.021	0.226	1.689	1.407
178	7	0.025	0.269	2.011	1.676
191	7½	0.029	0.312	2.332	1.944
200	7¾	0.031	0.334	2.493	2.078
203	8	0.032	0.344	2.574	2.145
216	8½	0.037	0.398	2.976	2.480
222	8¾	0.039	0.420	3.137	2.614
229	9	0.041	0.441	3.297	2.748
241	9½	0.046	0.495	3.700	3.083

Diameter Millimetres	Diameter Inches	Volume m^3/m	Volume ft^3/ft	Volume US gal/ft	Volume Imp gal/ft
248	9¾	0.048	0.517	3.860	3.217
254	10	0.051	0.549	4.102	3.418
279	11	0.061	0.657	4.906	4.088
305	12	0.073	0.786	5.871	4.893
311	12¼	0.076	0.818	6.112	5.094
324	12¾	0.082	0.883	6.595	5.496
381	15	0.114	1.227	9.169	7.641
438	17¼	0.151	1.625	12.144	10.120
445	17½	0.155	1.668	12.466	10.388
457	18	0.164	1.765	13.190	10.992
508	20	0.203	2.185	16.327	13.606
610	24	0.292	3.143	23.485	19.570
635	25	0.317	3.412	25.495	21.246
762	30	0.456	4.908	36.675	30.562
914	36	0.657	7.072	52.840	44.034

7. Completing the Well’s Structure

Chapter Description

This chapter covers the requirements for the finishing steps of new well construction. Some of the finishing steps include developing, venting, covering and securing the well. This chapter also covers affixing the well tag to a well.

There are other requirements and exemptions for finishing a new well that are not listed in this chapter because they do not relate to the structure of the well. For example a person constructing a well must complete and deliver a well record, show a water sample for visual examination, conduct a test of the well yield and disinfect a well. The well record and other requirements are covered in subsequent chapters.

Regulatory Requirements - Completing The Well's Structure

Relevant Sections - The *Wells Regulation*

- Well Pit – Subsections 12(7), 12(8) and 12(9)
- Well Pit Casing – Subsection 13(14)
- Covering the Well – Section 12.2 and Subsections 15.2(6) to (8)
- Surface Drainage – Section 12.3
- Casing Height – Subsections 13(8), 13(9) and 13(10)
- Development – Section 14.8
- Development by Surging – Subsection 14.4(2), paragraph 1, i, B
- Well Tag – Section 14.11
- Venting – Subsection 15.1(1)

The Requirements - Plainly Stated

The *Wells Regulation* requires the following regarding the finishing steps of the construction of a new well:

Covering the Well

If the well is left unattended during construction, the person constructing the well must cover the upper open end of the well securely to prevent entry of surface water and other foreign materials (see Chapter 9: Equipment Installation for further

information on well caps and covers).

Surface Drainage (Earth Mounding) around the Well:

The person constructing the well must ensure that the slope of the ground surface (surface drainage) is such that water will not collect or pond near the well. Preventing the collection or ponding of water can be ensured by properly mounding with earth around the well and outward from the well to direct surface water away from the well.

Casing Extent for New Wells in Overburden Aquifers

Unless exempted, a new well that obtains water from an overburden formation, must be cased:

- from the water intake zone,
- to at least 40 cm (16 inches) above the highest point on the ground surface within 3 m (10ft) radially from the outside of the casing after the land is properly mounded for surface drainage as measured on completion of the well's structural stage.

Casing Extent for New Wells in Bedrock Aquifers

Unless exempted, a new well that obtains water from a bedrock formation, must be cased:

- from the bedrock,
- to at least 40 cm (16 inches) above the highest point on the ground surface within 3 m (10ft) radially from the outside of the casing after the land is properly mounded for surface drainage as measured on completion of the well's structural stage.

Casing Height Exemption for New Driven Point or Jetted Point Wells

An exemption to the minimum casing height requirement of 40 cm (16 inches) above the ground surface exists if the new well is made by the use of a jetted point or driven point and it has a visible, permanent marker.

To qualify for this exemption:

- the casing must extend a sufficient height to permit the attachment of a well tag;
- the casing must be at least as high as the highest point on the ground surface within a 3 m (10ft) radius of the well's casing after the ground surface is properly mounded with earth to direct surface drainage away from the well as measured on completion of the well's structural stage; and
- the permanent marker must identify the location of the well and be visible at all times of the year.

Well Pits

A new well must not be constructed with a well pit unless the new well is created by diamond drilling equipment in connection with mineral exploration.

A well pit must not be added to an existing well unless the existing well was created by diamond drilling equipment in connection with mineral exploration.

If a new drilled well is constructed with a well pit, the top of the casing of the drilled well must be at least 40 cm (16 inches) above the floor of the well pit and the well pit must be cased:

- from the bottom of the well pit,
- to at least 40 cm (16 inches) above the highest point on the ground surface within 3 m (10ft) radially from the outside of the well pit casing after the land is properly mounded for surface drainage as measured at the time the well pit is completed.

Reminder: All new well pits are banned in Ontario except for wells constructed by diamond drilling equipment that are also used in connection with mineral exploration. For further information on well pit installation see Chapter 9: Equipment Installation.

Well Caps or Covers

Dug or Bored

The top of the casing of a well that is constructed by digging or boring must be covered with a solid, watertight well cover, so that surface water and other foreign materials cannot enter into the well.

Drilled or Other

The top of the casing of a well that is not constructed by digging or boring must be sealed with a commercially manufactured vermin-proof well cap (this includes a properly installed and sealed sanitary well seal and a watertight and airtight well cap for a point well).

Exceptions to Well Cap or Cover Requirements

The cover, cap or seal is not required if all of the following criteria are met:

- A floor has been constructed around or adjacent to the casing of the well.
- A pump (including associated pump equipment such as a waterline connected to a pump) is installed above or adjacent to the well.
- The top of the casing is shielded in a manner sufficient to prevent the entry of any material that may impair the quality of the water in the well.
- The casing of the well is extended to at least 15 cm (6 inches) above the floor that has been constructed around or adjacent to the casing of the well.

Reminder: See Chapter 9: Equipment Installation for further information on well caps and covers.

Developing the Well

Before the structural stage of a new well is completed, debris (such as well cuttings, drilling fluids, etc.) must be removed from the well by developing the well until the well water is clear and free of sand.

For any new well, other than a well constructed by digging or by the use of a jetted or driven point, where a well screen is installed, the well must be developed after the placement of suitable sealant, using a surging method to remove fine grained soils.

Reminder: See definition of the "well's structural stage" in Chapter 2: Definitions and Clarifications, Table 2-1

Venting

When a new well is constructed, the well must be vented to the outside atmosphere in a manner that will safely disperse all gases unless the casing is used to transmit water out of the well.

Additional venting requirements may apply after pumping equipment is installed in the well.

Reminder: See Chapter 9: Equipment Installation for further information on venting.

Well Tags:

Before the structural stage of a new cased well is completed, a well tag from the Ministry must be obtained and affixed permanently to the outside of the casing, or to a permanent structure associated with the well. The affixed well tag must be visible and not hidden by the well cap, any other components of the well or equipment associated with the well.

If an alteration, other than a minor alteration, is made to a cased well that does not already have a well tag, a well tag from the Ministry must be obtained and affixed before the alteration is completed as per the first paragraph of this section.

If a cased well that already has a well tag is altered, the well tag must be safeguarded during the alteration. If the well tag is removed before the alteration is completed, it must be reaffixed as per the first paragraph of this section.

If a broken, defaced, illegible or otherwise unusable well tag is encountered when altering the well, including a minor alteration, the person altering the well must:

- obtain a new well tag from the Ministry and, before the alteration is completed, affix it as per the first paragraph of this section, and
- return the original well tag and a completed well record with respect to the replacement of the well tag to the Director within 30 days after the new well tag is affixed to the casing.

Reminder: For more information on well tags, see Chapter 13: Well Records, Documentation, Reporting & Tagging.

Relevant Sections - Additional Regulations Or Legislation

- *Ontario Water Resources Act*, R.S.O. 1990, Chapter O.40 – Subsection 30(1)
- *Environmental Protection Act*, R.S.O. 1990, Chapter E.19 – Subsection 14(1)

Well Record - Relevant Sections - Completing Construction

Figure 7-1: Well Record - Relevant Sections

Figure 7-1 shows a sample of the details to be completed on the well record with regards to completing the well.

Key Concepts

What To Consider When Completing The Well's Structure

Purpose Of The Well

When completing the well's structure, it is important to consider the reason for the well installation. The well's purpose will impact how the structure should be completed. For example, a municipal well may have to be installed in a pump house without a well cover.

Well Development

The purpose of well development is to remove any water or drilling fluids introduced into the well during drilling, stabilize the filter pack and formation materials opposite the well screen, minimize the amount of fine-grained sediment entering the well; and improve well efficiency and inflow of water into the well. Granular material (e.g., sand and silt) in the well water may have serious implications for the well owner's pumping equipment, waterline and plumbing.

Casing Height And Mounding

A sufficient height of casing above the ground surface, or above the floor of a well pit, helps to prevent the entry of surface water or foreign materials through the top of the well. In addition, mounding earth immediately around the casing helps to direct surface drainage away from the well to reduce the risk of surface water ponding at the well site and to reduce the potential for surface water to migrate down the side of the well casing into the well.

Well Caps, Covers and Securing The Well

Securing and covering the casing are the primary safeguards against unauthorized entry into the well, vandalism or tampering. Well caps and covers also protect against the movement of surface water or foreign materials from the surface into the well. Securing the well includes ensuring that the well cap, seal or cover is on properly and may include the use of a protective cover with locking cap, barriers or fences.

Well Tag (Identification)

Well identification numbers link wells in the field with written records. The Ministry issues alphanumeric well tags that must be affixed to all new wells and many altered wells. The well tag will link the well or the well cluster to a corresponding well record. A well tag or number is important as it links detailed information of the construction process and design of the well. This information is crucial to persons who have to:

- locate wells in the field,
- test and sample, or
- maintain, or if necessary, alter or abandon a well.

Well Development

Well development has four broad objectives:

1. To remove any water or drilling fluids introduced and fine materials disturbed during the construction of the well in order to obtain representative groundwater information and sediment-free water samples. In addition, this will minimize the potential for damaging pump equipment.
2. To correct damage to the hole wall and adjacent native geological material caused during construction. This creates natural physical aquifer conditions to help determine hydraulic parameters such as hydraulic conductivity (K).
3. To stabilize the filter pack and formation materials opposite the well screen. Development creates a graded zone (i.e., natural sand and/or gravel pack with larger to smaller material away from the water intake zone) around the well screen in an overburden well (see Figure 7-2).
4. To maximize the efficiency of the well and hydraulic connection between the well intake zone and the formation by decreasing the potential for lower porosity and permeability near and at the well intake [1] .

These objectives are accomplished by applying some form of energy to the formation beside or below the well intake.

The *Wells Regulation* indicates that before the structural stage of a new well is completed, the person constructing the well must do everything reasonably practicable to remove any debris, including well cuttings and drilling fluids, from the well by developing the well until the well water is clear and free of sand.

Also, for any new well, other than a well constructed by digging or by the use of a jetted or driven point, where a well screen is installed, the well must be developed after the placement of suitable sealant, using a surging method to remove fine grained soils.

Clear
: means all debris, including well cuttings and drilling fluids, has been removed from the well and well water; and the water is transparent or unclouded.

Reminder: “Clear” does not mean without any naturally occurring colour associated with the well water. For example, groundwater can turn an orange colour where naturally occurring iron is present in the groundwater and formation. Groundwater can turn a black colour where naturally occurring iron sulphide is associated with the groundwater. Both these samples could be “clear” for the purpose of well development requirements in the *Wells Regulation*.

Best Management Practice – Well Development

If all reasonable steps have been taken to develop the new well and it continues to produce water that visually has naturally occurring colour or sediment, drill cuttings or drilling fluids, the person constructing the well should notify the well purchaser and owner of the land that the condition exists to determine what next steps are necessary. With this information, the well purchaser and well owner can take the appropriate precautionary steps in designing, purchasing and installing pumping and treatment equipment in the well and water distribution system, or, if necessary, in properly abandoning the well.

Benefits Of Well Development

In general, development procedures have the following beneficial purposes:

- Protecting the pumping equipment, waterline and plumbing from damage due to granular material (e.g., sand and silt) in the well water.
- Reducing the compaction and intermixing of grain sizes produced during construction by removing fine material from the pore space.
- Increasing the natural porosity and permeability of the formation near the well intake by removing the finer grain material.

Specific To Drilled Wells:

Well Development:

- removes the filter cake, or drilling fluid film that coats the hole, and removes much or all of the drilling fluid and natural formation solids that have invaded the formation during well construction,
- creates a graded zone (e.g., natural sand or gravel pack larger to smaller material) around the screen in an overburden well, so that the well yields sand-free water (see Figure 7-2), and
- dislodges drill cuttings that may be plugging water bearing fractures in bedrock wells.

Figure 7-2: A Properly Developed Overburden Drilled Well [2]

Figure 7-2 shows how development (by surging water back and forth) has created a graded zone (i.e., natural sand or gravel pack with larger to smaller material away from the water intake zone) around the well screen in an overburden well.

Development Methods

There are many different factors that contribute to the method chosen to develop a well.

The selection of the appropriate development methods from those listed below must be based on:

- equipment available and accessibility to the well,
- geology and hydrogeology (depth of aquifer in relation to well screen),
- well construction system and method used (cutting action used, flushing media),
- type of well installation (e.g., casing, annular space),
- diameter and depth of the well,
- diameter, slot size and length of the well screen and the filter pack,
- hydraulic characteristics of the well (e.g., static water level),
- health and safety requirements for field staff,
- types of contaminants and proper disposal of discharge water, and
- Permit To Take Water, discharge approvals and other regulatory requirements

Well Development Techniques

Below is a list of some methods of well development for various scenarios. In some cases multiple techniques may be used to develop a well. The methods include:

- surging or washing/backwashing with plunger devices (forcing water to flow in and out of a well screen by operating a plunger up and down in the well),
- air lift development (using an air lift to alternately surge and pump the well),
- air burst development (a combination of pumping with air and using large bursts of air injected into the well screen or bedrock hole to surge the formation),
- manual development (using a inertial lift pump),
- jetting (the use of high velocity jetting tools),
- over-pumping with a submersible pump (a combination of pumping with air and using large bursts of air injected into the well screen or bedrock hole to surge the formation),
- bailer surging, and
- hydrofracturing (hydrofracing) (bedrock well only).,

The *Wells Regulation* - Any water introduced into the well during development or other well construction must not impair the quality of any well water or cause an adverse effect on the natural environment.

Reminder: The container used to transport any water brought to the site for the well development must not contaminate the water in the container.

Surging

Surging is the simplest and the most common method of development. The clay, silt and sand grains are agitated by rapidly moving a plunger up and down in the well. This action moves the water in and out of the formation and well screen as shown in Figure 7-3. Water containing fine granular material moves into the well casing. The granules tend to settle to the bottom of the well so they can be removed by pumping water or air or bailing.

Figure 7-3: Surging

Reminder: This figure is not to scale, it is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with other requirements found in the *Wells Regulation*.

Air-Lift Pumping

Another method available for developing a well is pumping with an air-lift pump at a high rate for a brief period, to draw water and formation fines into the well. Then the pump is shut off to “slug” the well, loosening formation fines, and breaking sand bridges in the formation and filter pack.

Reminder: Further information on well development can be found in Groundwater and Wells: Third Edition [3]

Casing Height And Mounding

Surface Drainage(Mounding)

Mounding earth immediately around the casing to direct surface water away from the well helps to reduce the risk of surface water ponding at the well site and to reduce the potential for surface water to migrate down the side of the well casing into the well.

The *Wells Regulation* - The person constructing the well must ensure that the surface drainage is such that water will not collect or pond in the vicinity of the well.

Best Management Practice – Mounding

To prevent the pooling of water around the well, the following should be considered:

- In areas subject to frost heave, a soil or bentonite/sand layer should be placed adjacent to the casing and sloped to direct water drainage away from the well.
- In areas not subject to frost heave (e.g., in a heated pump house), a concrete pad should be installed and sloped slightly to direct water drainage away from the well.

Casing Height

The casing height must be checked at the completion of the well's structure to ensure it complies with the *Wells Regulation*.

The *Wells Regulations* - Unless exempt, for any new well, the casing height must be at least 40 cm (16 inches) above the highest point within a 3 m (10ft) radius of the well's casing after the ground surface is properly mounded with earth to direct surface drainage away from the well as measured on completion of the well's structural stage. Figure 7-4 illustrates these measurements.

Reminder: There are exemptions to the above well casing height requirement for a new well constructed by the use of a driven point or jetted point or with a well pit. See "Casing Height for New Point Wells Constructed by Driving or Jetting" of this chapter and Chapter 9: Equipment Installation, "Well Pit Floor" section for further information.

The *Wells Regulation* - If an existing well casing extends to a height of 40 cm (16 inches) or more above the ground surface, the height of the casing cannot be reduced to a height of less than 40 cm (16 inches) above the ground surface. This includes cutting the casing or increasing the elevation of the ground surface adjacent to the well. Therefore, persons who work on pumps and equipment in a well, developers, general contractors, landscapers and well owners should be aware of the minimum height of the well casing requirement above the land surface. If the ground surface is raised, then the owner of the land or a properly licensed person working on the well must extend the well casing to the minimum required height.

Reminder: If work must be performed to raise the well casing, the person hired to do the work must have, or work for a business that has, a valid well contractor licence and have the proper prescribed class of well technician licence. See Chapter 3: Well Contractors & Well Technicians – Licences, Responsibilities & Exemptions for further information.

Figure 7-4: How to Measure Casing Height Above The Ground Surface For A New Well (Other Than A Well Constructed By The Use Of A Jetted Point And/Or Driven Point With A Permanent Visible Marker Identifying The Well)

Reminder: The same method of measuring casing height applies to new jetted and driven point wells that have been constructed with a permanent visible marker. In that case, the casing must extend a sufficient height to permit the attachment of the well tag and be at least as high as the highest point on the ground surface within 3 m (10ft) radially from the outside of the well casing.

Reminder: This figure is not to scale, it is for illustrative purposes for this chapter only, and does not necessarily represent full compliance with other requirements found in the *Wells Regulation*.

Casing Height When Multiple Casing Are Used In A Well

In some cases, multiple casings of different diameters are installed in a well to reach a water producing zone. This type of installation is common in municipal wells, some flowing wells and other large water taking wells. For example the initial 20 m (65ft) of the hole may have a 40 cm (16 inches) diameter casing. The next 20 m (65ft) of the hole has a 30 cm (12 inches) diameter casing. Unless exempt, at least one of the casings has to meet the height requirements in the *Wells Regulation*.

The *Wells Regulation* - In the case of a multi-level well with an outer permanent casing and multiple inner casings:

- all casing extending from well screens must meet the height requirements in the *Wells Regulation* as described in the "Plainly Stated" section of this chapter, or
- the outer permanent casing must meet the height requirements in the *Wells Regulation* as described in the "Plainly Stated" section of this chapter.

Reminder: See Chapter 5: Constructing the Hole, Casing & Covering the Well.

Casing Height for New Point Wells Constructed by Driving or Jetting

The *Wells Regulation* - An exemption to the minimum casing height requirement of 40 cm (16 inches) above the ground surface exists if the new well is made by the use of a jetted point or driven point, and it has a visible, permanent marker.

In these cases, the casing must:

- extend a sufficient height to permit the attachment of a well tag, and
- be at least as high as the highest point on the ground surface within a 3 m (10ft) radius of the well's casing for any new well after ground surface is properly mounded with earth to direct surface drainage away from the well as measured on completion of the well's structural stage.

The permanent marker must also identify the location of the well and be visible at all times of the year.

Best Management Practice – Casing Height

Where feasible, casing height for a well should go beyond the minimum casing height requirements, particularly in an area prone to flooding, such as a flood plain. This will also allow for easier maintenance and identification purposes. Wells especially for driven and jetted point wells.

Special casing height considerations may have to be taken to vent gas from a well safely and keep the top of the casing above the top of the static water level in a flowing well.

To ensure a sufficient height of casing above the ground surface, it is also important to consider the proposed final grade of the property after landscaping.

When extending the casing of a jetted or driven point well above the ground surface, the person constructing a point well should take the necessary steps in the design and installation to prevent water from freezing within the point well system.

Well Covers And Securing The Well

Covering The Well

The *Wells Regulation* requires that if the well is left unattended during construction, the person constructing the well must cover the upper open end of the well securely in a manner sufficient to prevent the entry of surface water and other foreign materials

Reminder: See Chapter 9: Equipment Installation for further information on well caps and covers.

Dug Or Bored

The *Wells Regulation* - The top of the casing of a well that is constructed by digging or boring must be covered by the person constructing the well with a solid, watertight well cover sufficient to prevent the entry of surface water and other foreign materials into the well.

Reminder: A flat cover with an access lid embedded in the cover is not considered to be watertight. A well cover, such as a one piece solid concrete well cover, is considered to be solid and watertight if it is constructed and installed in a manner sufficient to prevent the entry of surface water and other foreign materials into the well. For clarification on the term "watertight" see Table 2-3 of Chapter 2: Definitions & Clarifications.

Reminder: See Chapter 9: Equipment Installation for graphics and further details on caps and covers.

Drilled Or Other

The *Wells Regulation* - The top of the casing of a well that is not constructed by digging or boring must be sealed by the person constructing the well with a commercially manufactured vermin-proof well cap. This includes a properly installed and sealed sanitary well seal commonly used in wells located in well pits and pump houses. This also includes a watertight and airtight well cap for a well that is constructed with the use of a well point.

Reminder: See Chapter 9: Equipment Installation for graphics and further details on caps and covers.

Well Cap Exemptions For Drilled Or Other

The *Wells Regulation* - Every well, other than a dug or bored well must be fitted with a commercially manufactured vermin-proof well cap, unless all of the following criteria are satisfied:

- a floor has been constructed around or adjacent to the casing of the well,
- the casing of the well is extended to at least 15 cm (6 inches) above the floor that has been constructed around or adjacent to the casing of the well,
- a pump is installed above or adjacent to the well, and
- the top of the casing is shielded in a manner sufficient to prevent entry of any material that may impair the quality of the water in the well.

Reminder: See Chapter 9: Equipment Installation for graphics and further details on caps and covers.

Venting The Well

The *Wells Regulation* - When constructing a new well, the person constructing the well must ensure that the well is vented to the outside atmosphere so that all gases will safely disperse from the well. Additional venting requirements may apply after pumping equipment is installed in the well.

The purpose of the vent is to allow the well to breathe, which enables pressures to equalize (e.g., when water is drawn out, air can enter the well keeping the column of water at atmospheric pressure). The vent also allows for the dispersal of natural gases to the outside atmosphere. In many cases, a properly designed vent is required to be installed on a well to safely disperse a gas that is poisonous, explosive or otherwise hazardous.

Reminder: See Chapter 12: Equipment Installation for additional information on venting requirements.

Figure 7-5: Watertight Cap With Screened Air Vent Above The Well Cap

When the vent is attached to the top of a well cap as shown in Figure 7-5 the vent can be extended a significant distance above the well cap to safely disperse any explosive or poisonous gases. This type of system can also elevate the vent above potential flood elevations to reduce the risk of flood waters entering the well through the vent.

Special Considerations For Venting

Flowing Wells

Flowing wells are not exempt from the regulatory requirement for venting unless the casing is used in some way to transmit water out of the well.

A mechanical or inflatable packer, with a valve to allow air into and out of the well during pumping, may be installed to vent the well.

The *Wells Regulation* - Where a well is constructed and natural gas is encountered, the person constructing the well must notify the well purchaser, the owner of the land, and the Director that the condition exists.

If a well is producing a natural gas or other gas, the well owner must:

- take the necessary steps to manage the gas in a way that prevents any potential hazards,
- properly abandon the well, or
- seek the written consent from the Director to allow for the continued use of the well.

Reminder: Special precautions and procedures will be important when constructing wells and where gases are expected. Gases will need to be managed in a manner sufficient to prevent hazards. See the "Encountering Gas, Contamination and Water Quality" section of Chapter 5: Constructing the Hole, Casing & Covering the Well for further information and best management practices dealing with natural gas.

Well Tags

The *Wells Regulation* requires that, before the structural stage of a new cased well is completed, a well tag from the Ministry be obtained and affixed permanently to the outside of the casing or to a permanent structure associated with the well. The affixed well tag must be visible and not hidden by the well cap and any other components or equipment associated with the well.

The *Wells Regulation* - If an alteration, other than a minor alteration, is made to a cased well without a well tag, the person making the alteration must obtain and affix a Ministry well tag as described above, before the alteration is completed.

The *Wells Regulation* - If a cased well that already has a well tag is altered, the well tag must be safeguarded during the alteration. If the well tag is removed before the alteration is completed, it must be reaffixed, as described above.

The *Wells Regulation* - If an alteration, including a minor alteration, is made to a well with a well tag that is broken, defaced, illegible or otherwise unusable the person making the alteration must:

- obtain a new well tag from the Ministry and, before the alteration is completed, affix it to the well casing or a structure associated with the well, and
- return the original well tag and a completed well record with respect to the replacement of the well tag to the Director within 30 days after the new well tag is affixed to the casing.

Figure 7-6: Sample Mock Up Of Well Tag

Reminder: For further information on tagging and completing well records for a well cluster, please see Chapter 13: Well Records, Documentation, Reporting & Tagging and the definitions of "well cluster" and "minor alteration" in Chapter 2: Definitions & Clarifications Table 2-1.

8. Well Disinfection

Chapter Description

This chapter covers the importance of disinfecting pumping equipment and wells during initial construction, alterations and maintenance activities. It details the process required to comply with the *Wells Regulation*. Information on proper sampling and testing of water, safety issues and hazards is also provided.

This chapter does not cover ongoing well maintenance for existing wells. For information on maintenance, see Chapter 13: Maintenance & Repair.

Regulatory Requirements - Disinfection

Relevant Sections - The *Wells Regulation*

Disinfection - Section 15

The Requirements - Plainly Stated

The *Wells Regulation* requires the following for Well Disinfection:

After New Well Construction is Complete

Unless exempt, on the day the well's structural stage is complete, the person constructing the well shall:

- remove all debris from the well, and
- ensure:
  - the water in the well is dosed to a concentration between 50 mg/L and 200 mg/L of free chlorine and is left undisturbed for at least 12 hours.
  - the water in the well is not used for human consumption until the steps listed in the "Shock" Chlorination Steps section of the Plainly Stated are followed.

If the water in the well is not to be used for human consumption, no further disinfection steps are required.

If the water in the well is to be used for human consumption and unless exempt, the person constructing the well must follow the requirements in steps 1 to 4 listed in the "Shock" Chlorination Steps section of the Plainly Stated.

Installing Pumping Equipment in a Well or Altering an Existing Well:

Unless exempt, the person installing a pump or altering a well must follow Steps 1 to 4 in the "Shock" Chlorination Steps section of the Plainly Stated.

Exemption - Disinfection

The person does not have to follow Steps 1 to 4 in the "Shock" Chlorination Steps section of the "Plainly Stated" in the following circumstances:

- The well is considered a "flowing well", "test hole" or "dewatering well".
- The person performs a "minor alteration" on an existing well.
- The *Wells Regulation* exempts the installation of equipment for certain sampling, testing or monitoring activities.
- The person constructing the well has written approval from the Director to use another method of disinfection and the approved method is complied with.
- The person has replaced a pump, including associated pumping equipment, that is installed above or adjacent to a well or in a well pit unless the replacement involves the removal of a well cover or well cap.

"Shock" Chlorination Steps

The person constructing the well must ensure the following steps set out in the *Wells Regulation* are taken:

1. The well water is dosed to a free chlorine concentration between 50 mg/L and 200 mg/L (initial dose) as soon as possible after construction or installation of pumping equipment and all debris has been removed from the well.
2. The well water is tested for free chlorine residual at least 12 hours and not more than 24 hours after the water is chlorinated.
3. If the test indicates the concentration of free chlorine residual in the well water is less than 50 mg/L or more than 200 mg/L, the person constructing the well must do the following steps, in the order shown below, as soon as reasonably possible:
   - Pump the water out of the well until the concentration of free chlorine residual in the well water is less than 1 mg/L.
   - Re-dose the well water to a concentration of not more than 200 mg/L of free chlorine.
   - Test the well water for a free chlorine residual 12 to 24 hours later.
   - If the test again indicates the concentration of free chlorine residual in the well water is less than 50 mg/L or more than 200 mg/L, these steps must be repeated. The Alternate Method section in the Plainly Stated discusses a possible alternative if the testing repeatedly shows a free chloring concentration that is too low.
4. If the test indicates the concentration of free chlorine residual in the well water is between 50 mg/L and 200 mg/L, the person constructing the well must do the following:
   - Pump the water out of the well until the concentration of free chlorine residual in the well water is less than 1 mg/L.

Reminder: All reasonable care should be taken to ensure that chlorinated well water is not pumped out in a quantity, concentration, or under conditions that may impair the quality of the surface water or groundwater, or that cause, or may cause, adverse effects to the natural environment. See the "Handling Heavily Chlorinated Water Discharge" section in this chapter for further information.

Use of Well During Dosing and Testing

In between the dosing and testing outlined in the "Shock" Chlorination Steps section of the Plainly Stated, no person must disturb the well or use the water for any purpose.

Written Records of Test Results

The person who is responsible for ensuring that the water is tested for free chlorine residual must ensure the well purchaser is provided with a written record of the test results before the well is used as a source of water for human consumption.

Special Circumstances

The "shock" chlorination process after the initial dosing (i.e., Step 1 in the "Shock" Chlorination Steps section of the Plainly Stated) does not apply to an alteration of a well if all of the following are satisfied:

- The alteration involves the urgent replacement or repair of a pump, including associated equipment, that unexpectedly failed.
- No water supply is immediately available as an alternative to the water from the well.
- The well purchaser provides written instructions to the person who undertakes the well alteration to discontinue the disinfection process after dosing the well to a concentration not less than 50 mg/L and not more than 200 mg/L free chlorine.

In these cases, the following is required:

- The well purchaser must ensure that, before the well water is used for any purpose, water is pumped from the well until no odour of chlorine is detected in the well water.
- The person who undertakes the alteration must retain the written instructions referred to above for two years.

Relevant Standards

American Water Works Association (AWWA). 2003. ANSI/AWWA C654 -03 – "Disinfection of Wells." AWWA, Denver, CO, 2003. AWWA website.

American Water Works Association (AWWA). 2006. ANSI/AWWA A100-06 – "Minimum Requirements for Vertical Water Supply Wells." AWWA, Denver, CO, 2006. AWWA website.

NSF International Standard/American National Standard 60, 2009. "Drinking Water Treatment Chemicals - Health Effects." NSF International, Ann Arbor, MI 2009. NSF website.

Reminder: The standards cited in this document are current at the time of printing. Check current documents for recent updates.

Relevant Sections - Additional Regulations Or Legislation

Ontario Regulation 169/03 as amended made under the *Safe Drinking Water Act*

Well Record - Relevant Sections - Disinfection

The *Wells Regulation* - Figure 8-1 shows a sample of the details to be completed on the well record relating to disinfection.

Reminder: By checking "Yes" in this section of the well record the person constructing the well is confirming that the disinfection requirements in the *Wells Regulation* have been followed.

Reminder: A person can only select "No" in this section of the well record when exemptions to disinfection apply, such as flowing wells and minor alterations.

Figure 8-1: Well Record - Relevant Sections

Key Concepts

What to Consider When Disinfecting A Well

Purpose Of Disinfection

Disinfection protects Ontario's waters by reducing pathogens.

The disinfection steps provide an adequate level of removal or inactivation of pathogenic organisms that may be present in the well or groundwater [1] or introduced during the well construction process and prevent heavily chlorinated water from affecting crops, surface water courses or other activities.

This chapter covers disinfection during and after well construction and installation of equipment in a well. This chapter does not include disinfection treatment (primary or secondary) on municipal distribution systems or treatment on private domestic water supplies.

Process Of Disinfection

With respect to well construction and installation of equipment in a well, the process of disinfection involves the following [2] :

- initial steps, including:
  - following sanitary practices when constructing a new well,
  - properly developing a new well, and
  - removing any debris from a well
- thorough flushing of the well,
- treating with a properly prepared chlorine solution,
- discharging of heavily chlorinated water from the well and the plumbing, and
- collecting and analyzing water samples.

When Must Disinfection Take Place?

A well can become contaminated during well construction and pump installation.

The *Wells Regulation* - While every effort should be made to keep the equipment used and the environment worked in contaminant free, the *Wells Regulation* requires that, unless exempt, a person must disinfect the well water after:

- constructing a new well,
- installing, including re-installing, the pumping equipment in a well,
- deepening or extending a well, or
- conducting an alteration or a repair on an existing well or on equipment in a well except for a minor alteration.

The person does not have to disinfect the well in the following circumstances:

- The well is considered a "flowing well", "test hole" or "dewatering well".
- The person performs a "minor alteration" on an existing well.
- The *Wells Regulation* exempts the installation of equipment for certain sampling, testing or monitoring activities.
- The person constructing the well has written approval from the Director to use another method of disinfection and the approved method is complied with.
- The person has replaced a pump, including associated pumping equipment, that is installed above or adjacent to a well or in a well pit unless the replacement involves the removal of a well cover or well cap.

Use Of Chlorinated Water In The Disinfection Process

Chlorine, in its various delivery forms, is generally a good disinfectant for indicator organisms and most pathogenic organisms. Treatment with chlorine products, after the well is properly cleaned and pumped, is an inexpensive and effective way to disinfect the pumping system and the well water. Although chlorinating the water is a good treatment for a well and pumping equipment, its effectiveness depends on a number of factors, including the following:

Form – The most effective form of chlorine solutions for dosing well water is liquid sodium hypochlorite (such as unscented bleach). When used properly, it is the easiest to mix to achieve a concentration of not less than 50 mg/L, and not more than 200 mg/L, of free chlorine throughout the column of water in the well.

Granular calcium hypochlorite is another choice but it is difficult to mix with water. It is best to avoid the use of chlorine puck or tablet products to dose the well as they can become lodged in the well, corrode the equipment and may not provide the proper concentration for the required amount of time.

It is also best to avoid the use of chlorine products used for pools as they typically contain other chemicals such as algaecides and surfactants.

Chlorine concentration – The *Wells Regulation* requires a dose to create a free chlorine of not less than 50 mg/L (0.007 oz/gal) and not more than 200 mg/L (0.032 oz/gal). This range is based on recommendations provided by Ontario's Advisory Council on Drinking Water Quality and Testing Standards.

Free chlorine residual – The amount of chlorine available that acts as an oxidizer (kills micro-organisms). The free chlorine is comprised of hypochlorous acid (HOCl) and hypochlorite ion (OCl^-) that is not combined with ammonia NH_3) or other compounds in water.

Contact time – The longer the microorganisms are in contact with the free chlorine, the more effective the disinfection. The *Wells Regulation* requires a minimum contact time of 12 hours, but not more than 24 hours [3] .

Agitation – Dosing a well by pouring a chlorine solution into a well is not enough to ensure it is completely mixed to the required concentration. To ensure the free chlorine residual is at the correct concentration throughout the entire water column, well water should be agitated while avoiding the suspension of sediment from the bottom of the well into the water column.

pH of water – The effectiveness of free chlorine is maximized at pH levels between 6.0 and 7.0 [4] . As chlorine solutions are highly alkaline (i.e., high pH), the dose of chlorine solution in the well increases the pH of the well water and can diminish the effectiveness of the free chlorine. Therefore, it is important to follow the 50 mg/L to 200 mg/L concentration range requirements for free chlorine set out in the *Wells Regulation*.

Temperature – The effectiveness of free chlorine can change with temperature. Free chlorine is more effective at higher temperatures.

Interfering substances – Available chlorine will be used up by any inorganic and organic compounds in the well water which will reduce the concentration of free chlorine.

Biofilm - Biofilm is a slimy substance that attaches to sides of wells and pumping equipment. The slime consists primarily of nuisance microbes (e.g., iron oxidizing bacteria and sulphate-reducing bacteria) that can shield pathogens from the oxidizing action of the free chlorine and reduce the amount of available chlorine. Therefore, it is necessary that biofilm be removed before treating the well water with free chlorine.

Inital Steps For New Wells

Sanitary Practices

The initial step for disinfection begins with adopting sanitary practices to prevent contaminants from entering the well during construction. This is done by following sanitary practices during storage, transport, handling and installation of well components and equipment. Essentially, anything that comes into contact with the water in the well can potentially introduce contaminants in the well.

Each of the scenarios listed below presents a potential cause of contamination to a well:

- Pumping equipment that has been placed on a recently fertilized lawn.
- Pumping equipment that has been placed on a lawn where pathogens from soil and animal waste exist.
- Construction equipment that has been dragged through a field where cows or other domestic animals graze.
- Contaminated sand or gravel filter pack material that will be installed around a well screen
- A storage tank that recently held contaminated water
- A faulty well cap that can act as a direct pathway for foreign materials to enter the well
- Unsealed annular space outside the casing can provide a pathway for surface water runoff to enter the well
- Improper use of grease, lubricants and drilling additives during construction can promote bacterial growth [5]
- Contaminated water from ponds, rivers and lakes has been used in the construction process

Best Management Practice – Preventing Contamination During Storage and Transportation

To prevent contamination during storage and transportation of well components, the following procedures [6] should be adopted:

- Water supply equipment and construction materials should be kept off the ground by placing them on clean sheeting.
- Vehicles that transport the equipment and materials should be clean.
- Equipment and materials on vehicles should be covered to protect them from road dirt and grit.
- The components and materials should be kept in their wrapping or boxes until just before use if the components and materials have been wrapped or boxed by the manufacturer.

Best Management Practice – Preventing Contamination During Construction

To prevent contamination from construction equipment or materials that come in contact with the water the following practices should be adopted:

- All equipment such as drill bits, drill rods or backhoe shovel should be cleaned and sanitized with chlorinated water that has a free chlorine residual of not less than 200 mg/L [7] .
- An approved potable water supply (e.g., municipal water trucked in to the site, should be used during the construction process. The potable water source should have a free chlorine residual of at least 10 mg/L to suppress bacterial growth [8] .
- The water used in the construction process should be placed in clean containers [9] .
- All equipment should be kept off the ground by placing it on clean tarps or on the drilling rig until needed.
- The equipment should not be dragged on the ground.
- Any drilling mud or water with additives that may promote bacterial growth should be avoided.
- The use of excessive amounts of grease on drill rod tool joints should be avoided.

Disinfection For Sand Or Gravel(Filter Pack)

In addition to keeping materials clean during storage and transportation, a person installing sand or gravel (filter pack) during well construction should: [10]

- avoid, if possible, buying the material in bulk and storing it on-site to reduce the risk of exposing the material to sources of contamination such as soil bacteria, insects and animal feces,
- ensure the sand or gravel are free of all organic materials to reduce the potential for bacterial growth, and
- saturate the sand or gravel (filter pack) using chlorinated water with a free chlorine residual of at least 50 mg/L or a mixture of calcium hypochlorite tablets at a ratio of 113 g (¼ lb) to 227 g (½ lb) to a 22.7 kg (50 lb) bag of sand or gravel.

Reminder: The use of calcium hypochlorite tablets in hard water environments (hardness in excess of 100 mg/L) should be discouraged as this form is very slow to solubilize in the water. The condition will result in low levels of free chlorine over extended periods of time which may account for low levels of disinfection by-product formation. The situation becomes more critical in private wells, which are subject to limited pumping and long periods of inactivity.

Reminder: For details on installing sand or gravel (filter pack) in a well – See Chapter 5: Constructing, Casing and Covering the Well.

Well Development

Proper well development is required to remove fine soils, drilling fluids and drill cuttings from the well and surrounding formation. See Chapter 7: Completing the Well's Structure, for further details on well development.

Initial Steps For Existing Wells

During the alteration of an existing well or the installation of a pump (and related equipment) there is the potential for pathogens to be introduced into the well. Disinfection must occur to remove pathogens from the well.

Scaling, biofilm and other debris is commonly present on the side of the hole, casing or the equipment and in the well water. This organic and inorganic matter can reduce the available free chlorine. Biofilm can also shield pathogens from the oxidizing action of the free chlorine.

To remove this matter and prepare the well before the well is dosed with a chlorinated solution, the person disinfecting the well should follow the "Initial Steps for Existing Wells" Best Management Practice in this chapter.

Best Management Practice – Initial Steps for Existing Wells

To properly prepare an existing well for chlorination and other disinfection methods, all factors that can influence the effectiveness of the process should be minimized. Before chlorination takes place, a person should [11] :

- remove any debris in the bottom of the well,

- remove scale on the sidewalls of the casing or the hole,
- remove slime buildup from biofouling organisms, and
- evaluate and fix well construction deficiencies or problems, including but not limited to:
  - buried well head with a well seal that can become compromised over time and create a direct pathway for contamination,
  - unprotected horizontal water intake line (pipe) that can develop leaks due to physical damage or corrosion,
  - open horizontal water intake line (pipe) that can allow a direct pathway between the near surface and the well,
  - damaged or compromised well cap, cover or seal allowing surface water and other foreign materials to enter the well,
  - deteriorated, cracked or compromised casing due to physical damage or corrosion (e.g., oxidization, electrolysis) that can create openings and may allow surface water or other foreign materials to enter the well,
  - improperly sealed or unsealed annular space or eroded sealant in the annular space that can create a direct pathway to the well,
  - improperly abandoned wells on site that can cause re-contamination,
  - unsealed openings between the electrical conduit and the well cap allowing foreign materials, insects and other vermin to enter the well,
  - cross connections that can allow unwanted backflow to enter the well, and
  - improperly placed, screened or sized well vent that can allow surface water, foreign materials, insects and other vermin to enter the well,
- Clean the well by: [12]
  - scrubbing the inside of the casing with a swab, packer, brush or similar device,
  - removing debris from the bottom of the screen or hole with an air line, bailer or other method, and/or
  - removing suspended materials in the water by pumping the well water until it runs clear.

Reminder: If the building's plumbing also needs to be disinfected, a person should turn off and completely drain distribution waterlines, water heaters and storage tanks.

Reminder: Carbon filters, water softeners and other treatment units on the plumbing should be removed or bypassed. Highly chlorinated water can damage treatment units. It is important to follow the manufacturer's recommendations to ensure treatment systems are properly disinfected.

Reminder: It is important that water and debris be collected and disposed of in an approved manner or discharged to waste in an approved manner.

Thorough Flushing Of The Well(New & Existing)

Flushing is the process of pumping out the water to help rid the well of contaminants and debris. The scouring action of the moving water assists in removing scaling and biofilm from the sides of the well. Flushing is used:

- before the well is dosed with a chlorinated solution to prepare the well, and
- after the treatment period to remove the chlorine residual from the well. [13]

This section discusses flushing prior to chlorination. For flushing of the well after chlorination see the "Handling Heavily Chlorinated Water Discharge" section in this chapter.

Best Management Practice – Flushing the Water Supply

The following steps should be considered when flushing of a well:

- The pump should be installed as close to the bottom of the well as possible to ensure movement of the entire water column and removal of debris.
- The pump intake should be placed above the top of the well screen.
- The pump intake should be moved up and down in the well column, in some wells, as this will help with cleaning the sides of the well and removing material.
- The pumping rate should be maximized to provide a more effective flush. Care should be taken not to exceed the well's capacity as this could cause damage to the well, the pumping equipment and to the formation around the well.
- Low capacity wells should be flushed with injected potable water to clean the well out and remove contaminants
- Pumping the well as long as possible. It is recommended that a minimum of 20 volumes of the water column in the well be pumped [14] .

- It is important that water and debris be collected and disposed in an approved manner. Discharge water should not be disposed of in any river, lake, stream, wetland, septic system, pond or ditch.
- Flooding of property and roadways should be prevented.

Treatment Using "Shock" Chlorination

The simplest and one of the more effective ways to disinfect well equipment and the well water is to use a chlorine solution. The oxidizing action of the chlorine solution kills bacteria, viruses, protozoa and some protozoal cysts.

"Shock" chlorination is an effective treatment method that is done after the initial steps of developing, cleaning and flushing the well to eliminate pathogens.

Free chlorine degrades rapidly in the natural environment. As such an approval from the Ministry of the Environment and Climate Change is not required to disinfect a well with certain chlorine-based products (e.g., hypochlorite).

Forms Of Chlorine For Disinfection

1. Sodium Hypochlorite(Such As Typical Household Bleach)

Sodium hypochlorite is commonly found in products like household bleach and swimming pool disinfection products. It has a yellow colour and a chlorine smell. Household bleaches typically contain 3 to 6% available chlorine. Industrial strength commercial bleach and swimming pool products can contain 10 to 12% available chlorine. However, the use of swimming pool products is not recommended because they typically contain additives that may impair the quality of the well water.

Household bleaches containing sodium hypochlorite are routinely used in domestic wells and are recommended in "shock" chlorination treatment because:

- they are familiar and common household products
- calculating, measuring and mixing the required volume of liquid to achieve the required dose is less complicated than for other products (e.g., powders, tablets or pucks)
- they are safer to use than liquid chlorine, chlorine gas or calcium hypochlorite

However, only regular major brand bleach products should be used as the greater percentage of bleach products on the household market contain silicates, surfactants, silicon and/or thickeners. All of these additives will harm both the water quality and the performance of the water supply.

Reminder: A person who is going to use a bleach product for chlorinating well water should check the product's label to verify that additives such as surfactants or fragrances have not been added.

Reminder: The unstable nature of sodium hypochlorite makes it sensitive to temperature and light and therefore it has a limited shelf life. For example, sodium hypochlorite degrades extremely rapidly in the hot, sunlit cab of a truck. Purchasing and carrying small containers ensure a fresh supply for each well construction project.

Reminder: Sodium hypochlorite products are described as weight % of available chorine, weight % of sodium hypochlorite and trade %. To convert to weight % of available chlorine from trade % and sodium hypochlorite use the following:

Trade Percent = grams per litre (gpL) of available chlorine ⁄ 10
Weight % of available chlorine = gpL ⁄ 10 × specific gravity of solution
Weight % of available chlorine = Weight % of sodium hypochlorite ⁄ 1.05

Reminder: To minimize impacts to groundwater, it is important that all chlorine products used be approved for potable water use and be either fresh unscented bleach or must meet the NSF International Standard 60 for Drinking Water Treatment Chemicals – Health Effects, or an equivalent standard.

Reminder: Scented bleach or products such as swimming pool chlorine should be avoided as they typically contain additives such as surfactants, thickeners, stabilizers, perfumes, UV inhibitors, algaecides or other additives. These additives can impair the quality of the water and aquifer after disinfection and are not designed for potable water use.

Reminder: It is important to always check product labels to verify product contents and manufacturer's suggested usage as well as Material Safety Data Sheets (MSDS). See the "Safe Handling of Chlorine" section in this chapter for further information.

Reminder: Chlorine products should always be stored in a cool, dry and dark environment.

2. Calcium Hypochlorite(Dry - Powder, Granules Or Tablets)

Calcium hypochlorite is a white granular compound containing about 60 to 70% available chlorine, which is fairly stable when stored in a cool dry place. Calcium hypochlorite is available as granules, powders, tablets and pucks.

Calcium hypochlorite is not typically recommended for "shock" chlorination the following reasons:

- Calculations can be difficult with such a high concentration.
- The high potency and required agitation can cause difficulties in obtaining the free chlorine residual concentration range in the *Wells Regulation* (not less than 50 mg/L and not more than 200 mg/L).
- Greater safety precautions are needed when handling and using the product.
- Tablets should be avoided as they are slow to dissolve and may become lodged within the parts of the well and pumping components. If tablets are used, they should first be broken up and dissolved into a 20 litre (4 gallon) pail or tank.
- In limestone, marble and other calcium-rich environments, calcium hypochlorite can increase the concentration of calcium in groundwater that is already hard, causing partial plugging of well intakes, screens and water-bearing fractures [15] .

Reminder: When a calcium hypochlorite product is selected, it is important that it is approved for use in potable water and meets all applicable standards such as ANSI/AWWA B300 titled: AWWA Standard for Hypochlorites [16] and the NSF International Standard 60 for "Drinking Water Treatment Chemicals – Health Effects [17] ."

Effectiveness Of Chlorine

Free Chlorine Residual

When a chlorine solution is first added to water (i.e., when the well is dosed) the available chlorine will react with substances in the water, and on the surfaces inside the well. During this reaction, some of the available chlorine is used up by organic and inorganic matter and can no longer kill pathogens and disinfect the well. The remaining available chlorine is the free chlorine residual that can effectively react to any pathogens. Free chlorine residual consists of two main compounds: hypochlorous acid (HOCl) and hypochlorite ion (OCl^-). Hypochlorous acid is much more effective (80 to 200 times better) at killing pathogens than the hypochlorite ion.

Substance That Interfere With The Effectiveness Of Free Chlorine Residual

As indicated above, available chlorine will be used up by any inorganic and organic compounds in the well water which will reduce the concentration of free chlorine. Examples of common materials or properties that reduce the free chlorine concentration are:

- alkalinity,
- hydrogen sulphide (H_2S),
- methane (CH_4),
- iron,
- manganese,
- biofilm (iron oxidizing bacteria and sulphate-reducing bacteria),
- silt, and
- clay.

Therefore, additional cleaning of the well or additional chlorine solution may be needed to achieve the required free chlorine residual concentration range in the *Wells Regulation* (not less than 50 mg/L to not more than 200 mg/L).

Well Structure

In some cases the geologic environment and well structure play a role in the amount and placement of the chlorine dose. For example, injecting and mixing of the dose by a surge block is more appropriate in a well screen, whereas a jetting tool may be more appropriate in an open bedrock hole. Also, large open fractures in open bedrock wells may allow the calculated chlorine solution to move further away from the well. This may require more chorine solution to maintain the required free chlorine residual in the bedrock well.

pH Levels

Sodium hypochlorite (bleach) and calcium hypochlorite are alkaline (caustic). It is important to note that when a person adds these chlorine products to water, the pH will increase. The form of free chlorine residual is pH-dependent. High pH environments create more hypochlorite ions and significantly reduce the effectiveness of the treatment. Therefore, it is important not to use too high of a

concentration of these chlorine products. Hypochlorous acid production and thus, the effectiveness of free chlorine are maximized at pH levels between 6.0 and 7.0 [18] .

Best Management Practice – Adjusting the pH of the Chlorine Solution [19]

A person should consider controlling the pH to maximize the amount of hypochlorous acid available to kill pathogens. There are several commercial acid products on the market that can lower the pH of water that will be used to make the chlorine solution.

Any of the acid products used in the process must not impair the quality of the water in the well or the aquifer and should meet NSF International Standards for potable water or an equivalent standard.

A person performing disinfection should carefully follow the manufacturer's instructions when adding any acids to the water. Acid should be added to water in a storage tank to lower the pH to 4.5 to 5.0 [20] followed by adding a hypochlorite solution. A formula for distilled white vinegar is found in the "Formula for pH Control During Chlorination" section of this chapter.

A recommended acid includes:

- Acetic Acid(distilled white vinegar only)

Acids to avoid include:

- oxalic Acid – is dangerous to skin and eyes and produces oxalates which are poisonous,
- citric acid – is a food source for bacteria and difficult to get out of a well,
- muriatic (hydrochloric) Acid – is hazardous to handle, and
- phosphoric Acid – leaves phosphate residue behind.

Reminder: **caution!** Never add acid directly to a hypochlorite solution (e.g., bleach) as chlorine gas can be formed. Avoid exposure to the fumes from the acid container.

When acid has been added to the water to lower the pH below 5.0 followed by adding a hypochlorite solution, some chlorine gas will be produced. The chlorine gas will be produced for a short period of time until the hypochlorite raises the chlorine solution's pH above 5.0. Chlorine gas is toxic. Therefore, add the acid source to the water and then the hypochlorite solution only in a well ventilated area (see the section titled: "Safe Handling of Chlorine and Other Chemicals" in this chapter for further information.

Measuring pH

During the mixing of the water with the chemicals, the pH should be tested frequently to identify any risk of chlorine gas production, for other health and safety reasons and to verify that the correct pH (6.0 to 7.0) of the free chlorine residual solution has been achieved. Test papers and comparison charts, calibrated field test kits or calibrated meters should be used to test the mixtures for pH.

Figure 8-2: Measuring pH

Figure 8-2 shows a pH test strip being checked against a comparison chart. The test strip is placed into the solution and changes colour. The test strip's colour is matched to the colour on the comparison chart which has the corresponding pH value. In this example the test solution has a high pH.

Temperature

The effectiveness of free chlorine can change with temperature. Higher temperatures increase the amount of hypochlorous acid in the free chlorine making the treatment more effective. However, as groundwater is typically between 6 and 12°C, increasing the temperature of the well water is cost prohibitive, impractical and could impair the quality of the water.

Safe Handling Of Chloreine And Other Chemicals

Proper transportation, storage and use of chemicals must be observed during all phases of well construction. In accordance with the *Occupational Health and Safety Act* and regulations made under this Act, safe practices must be followed when dealing with chlorine products and solutions, acids and other chemicals used in the "shock" chlorination process. Extra caution should be used when working with acids and calcium hypochlorite tablets or powder and acids as they can cause chemical burns, fire, or explosion. Chlorine gas can

be released if the water used to make the chlorine solution is acidified below a pH of 5.0 and hypochlorite is then added to the water. Therefore, proper precautions should be in place to protect workers from any possible release of chlorine gas during the treatment process.

Best Management Practice – Precautions in the "Shock" Chlorination Process

Precautions in the "shock" chlorination process include, but are not limited to the following:

- Protective clothing, such as gloves, aprons, goggles and a vapour mask should be worn at all times when working with chlorine products and acids.
- The pH adjustment products (acids) should be added to the mixing water before the hypochlorite solution is added to reduce the risk of chlorine gas generation. To minimize exposure to fumes, this should always be done in a well ventilated area. Chemicals must not be mixed in a confined space or a poorly ventilated area.
- The Material Safety Data Sheet (MSDS) for any chemical product should be obtained and the guidelines followed. The MSDS will include:
    - the properties of the material,
    - the hazards associated with the material,
    - Personal Protective Equipment (PPE) required when using the material, and
    - first aid and medical attention information

"Shock" Chlorination Procedures

Calculating Chlorine Solution Dose Amounts Using Bleach

The *Wells Regulation* - When the water in the well is required to be disinfected, the person constructing the well must dose the water in the well to concentration of not less than 50 mg/L (0.008 oz/Imp gal) and not more than 200 mg/L (0.032 oz/Imp gal) free chlorine.

To determine the dose that will create a free chlorine residual of not less than 50 mg/L and not more than 200 mg/L, a person constructing a well or installing a pump should calculate the volume of well water in the well and then the amount of chlorine product needed to dose the well water.

The following calculations and tables in this section are provided to assist the person in calculating the correct dose for the well.

To Calculate The Volume Of Well Water In A Well

1. Well depth elevation and static water level elevation are measured.
2. Height of water column in well is calculated:

   = Well Depth elevation – static water level elevation

3. If the well opening is circular, the inner diameter of the well is measured.
4. The radius of the well is calculated:

   = diameter of well / 2

5. The radius is converted to the same units as the length of the water column.
6. The area of the well casing opening is calculated:

   $\Pi \times \text{radius}^2$
   or
   $3.14 \times \text{radius} \times \text{radius}$

7. The volume of well water in the well is calculated:

   = area of well casing opening × water column in the well

Reminder: To prevent calculation errors and incorrect doses, it is important to use consistent units (e.g., metric or Imperial).

Example

The well depth is 35 metres below the ground surface and the static water level is 5 metres below the ground surface.

Therefore, the water well column height is 35 m − 5 m = 30 m (100ft).

The inner diameter of the well casing is 16 centimetres (6 ¼ inches).

The inner radius of the well casing = diameter of well / 2 = 16cm / 2 = 8cm

All units are converted to metres.

Therefore, the inner radius = 8cm / 100 = 0.08m

The area of the well casing opening = $\Pi \times \text{radius}^2 = 3.14 \times 0.08\text{m} \times 0.08\text{m} = 0.02\ \text{metres}^2$

The volume of the water well column = area of well casing opening × water column in the well

$= 0.02\text{m}^2 \times 30\text{m}$
$= 0.6\ \text{m}^3$
$*1\text{m}^3 = 1{,}000\text{L}$
$0.6 \times 1{,}000 = 600\text{L}$

Percent Volume Of Bleach Required

Typical available chlorine concentrations of unscented bleach by weight (as noted on the product label): are as follows:

0.005% = 50 mg/L
0.02% = 200 mg/L
1% = 10,000 mg/L
5% = 50,000 mg/L
12% = 120,000 mg/L

To Dose 1 Litre Of Water To 50 mg/L Of Free Chlorine

Using typical fresh unscented bleach (5.25 % available sodium hypochlorite) with 5 % (or 50,000 mg/L) available chlorine

(1L × 50) / 50,000 = 0.0010 L of bleach

An alternative formula using percentages:

(1L × 0.005%) / 50,000 = 0.0010 L of bleach
= 1 mL (0.035 fl. oz.) of typical fresh unscented bleach needed to create a concentration of 50mg/L of free chlorine in 1 L of water

Using typical fresh unscented bleach (6 % available sodium hypochlorite) with 5.7 % (or 57,000 mg/L) available chlorine

(1L × 50) / 57,000 = 0.000088L of bleach

An alternative formula using percentages:

(1L × 0.005%) / 5.7% = 0.00088L of bleach
= 0.88 mL (0.031 fl. oz.) of typical fresh unscented bleach needed to create a concentration of 50mg/L of free chlorine in 1 L of water

Using industrial sodium hypochlorite (12.5 % available sodium hypochlorite) with 12 % (or 120,000 mg/L) available chlorine

(1L × 50) / 120,000 = 0.00042L of Bleach

An alternate formula using percentages:

(1L × 0.005%) / 12% = 0.00042L of bleach
= 0.42 millilitres (0.015 fluid ounces) of industrial sodium hypochlorite at 12 % available chlorine is needed to create a concentration of 50mg/L of free chlorine in 1 L of water

Reminder: There are about 227 mL in one Imperial cup. There are about 4.7 mL in one Imperial teaspoon and 28.4 mL in one Imperial fluid ounce.

To Dose 1 Litre Of Water To 200mg/L Of Free Chlorine

Using typical unscented bleach (5.25 % available sodium hypochlorite) with 5 % (or 50,000 mg/L) available chlorine

$(1L \times 200)/50{,}000 = 0.0040L$ of bleach

An alternative formula using percentages

$(1L \times 0.02\%)/5\% = 0.0040L$ of bleach
= 4 mL (0.14 fl. oz.) of typical fresh unscented bleach is needed to create a concentration of 200mg/L of free chlorine in 1 L of water

Using typical fresh unscented bleach (6 % available sodium hypochlorite) with 5.7 % (or 57,000 milligrams per litre) available chlorine

$(1L \times 200)/57{,}000 = 0.0035L$ of bleach

An alternative formula using percentages

$(1L \times 0.02\%)/5.7\% = 0.0035L$ of bleach
= 3.5 mL (0.12 fl. oz.) of typical fresh unscented bleach needed to create a concentration of 200mg/L of free chlorine in 1 L of water

Using industrial sodium hypochlorite (12.5 % available sodium hypochlorite) with 12 % (or 120,000 milligrams per litre) available chlorine

$(1L \times 200)/120{,}000 = 0.0017L$ of bleach

An alternative formula using percentages

$(1L \times 0.02\%)/12\% = 0.0017L$ of bleach
= 1.7 mL (0.06 fl. oz.) of industrial sodium hypochlorite at 12 % available chlorine is needed to create a concentration of 200mg/L of free chlorine in 1 L of water

To Calculate The Dose For The Column Of Well Water

Dose = Volume of Water in well × Dose for 1 litre of water

Reminder: Dose is dependent on what free chlorine concentration the person is targeting (i.e., from not less than 50 to not more than 200 milligrams per litre), and is also dependent on the % of available chlorine (e.g., 5, 5.25 or 12%).

Example

This example uses the above calculations and the previous well example where the 35 metre deep well has 600 Litres of water.

To obtain a concentration of 50 mg/L free chlorine using typical fresh unscented bleach with 5% available chlorine, the 600 Litres is multiplied by 1 mL/L = 600 mL (21 fl. oz.) of typical fresh unscented bleach

An alternative formula using percentages

$(600L \times 0.005\%)/5\% = 600$ mL of bleach

To obtain a concentration of 200 mg/L free chlorine using typical fresh unscented bleach with 5% available chlorine, the 600 Litres is multiplied by 4 mL/L = 2.4 L (84 fl. oz.) of typical fresh unscented bleach

An alternative formula using percentages

$(600L \times 0.02\%)/5\% = 2.4L$ of bleach

Figure 8-3: Common Measuring Cup To Assist In Calculating Amount Of Bleach

Tables To Calcuate Does Using Bleach

Tables 8-1 to 8-4 provide the amount of bleach needed to dose various diameters of wells that will create 50, 100, 150 or 200 mg/L of free chlorine per metre of water column. The calculations shown on the previous pages were used to derive Tables 8-1 to 8-4.

If a different concentration of bleach is used, the calculations shown on the previous pages can be used to determine the amount required to dose the well.

Notes regarding Tables 8-1 to 8-4

Reminder: The volume of bleach provided by the tables will have to be multiplied by the depth of the column of well water to determine the dose for the well. The calculations consider well volumes only and do not include water in the plumbing and the water used for mixing. For additional information see the final note below.

Reminder: To dose the entire well column, obtain the volume of bleach needed in millilitres from appropriate Table (Table 8-1 or Table 8-3) and multiply by the well water column height in metres.

Reminder: If the height of the well water column is measured in ft, the height of the well water column is divided by 5 and multiplied by the volume of bleach in fluid ounces obtained using Table 8-2 or Table 8-4.

Reminder: The tables provide the amounts of bleach required to achieve the target concentrations under the ideal conditions of neutral pH (i.e., 7 pH units), no turbidity and no total dissolved solids. Additional bleach will be required if these conditions are not met. Test strips or other methods are used to verify if the free chlorine residual achieved meets the *Wells Regulation* requirements of not less than 50 mg/L and no more than 200 mg/L. Not meeting the required range can reduce the effectiveness of the treatment and will require the treatment to be repeated.

Reminder: The values in the tables do not account for the volume of any mixing water (typically 25 L or up to 4 to 5 times the volume of the well water column) or, if required, the volume of water in the plumbing (e.g., installing a pump in an existing well). It is important to consider this factor prior to putting the well into use because additional bleach will be needed to achieve the required range (see Table 8-7 or Table 8-8).

Table 8-1: Amount (in Millilitres) of Bleach Required per 1 Metre of Well Water Depth to Create 50, 100, 150 and 200 mg/L of Free Chlorine where Bleach has Available Chlorine of 5% by Weight (Metric Measurements). (See Table 8-2 for the equivalent information provided in Imperial measurements.)

Diameter of Well in Centimetres	**Volume of Water per Metre of Water Depth in Litres**	**Vol. of Bleach needed in mL to Obtain 50 mg/L for Each Metre of Water Depth**	**Vol. of Bleach needed in mL to Obtain 100 mg/L for Each Metre of Water Depth**	**Vol. of Bleach needed in mL to Obtain 150 mg/L for Each Metre of Water Depth**	**Vol. of Bleach needed in mL to Obtain 200 mg/L for Each Metre of Water Depth**
3.8	1.1	1.1	2.3	3.4	4.5
5	2	2	3.9	5.9	7.9
6	3	3	5	8	10
11	9	9	18	27	37
13	14	14	28	42	56
16	20	20	40	59	79
18	27	27	53	80	106
21	34	34	69	103	138
61	292	292	583	875	1167
76	456	456	912	1367	1823
91	656	656	1313	1969	2625

Reminder: The formula used to calculate this table is based on common well casing diameters in inches. The formula calculates the metric equivalent for diameter, litres per metre and then millilitres based on the initial industry standard diameter. The calculated numbers have then been rounded.

Table 8-2: Amount (in Fluid Ounces) of Bleach Required per 5 ft of Well Water Depth to Create 50, 100, 150 and 200 mg/L of Free Chlorine where Bleach has Available Chlorine of 5% by Weight (Imperial Measurements) (See Table 8-1 for the equivalent information provided in metric measurements.)

Diameter of Well in Inches	**Volume of Water per 5ft of Water Depth in Fluid Ounces**	**Vol. of Bleach Required in Fluid Ounces to Obtain 50 mg/L for Each 5ft of Water Depth**	**Vol. of Bleach Required in Fluid Ounces to Obtain 100 mg/L for Each 5ft of Water Depth**	**Vol. of Bleach Required in Fluid Ounces to Obtain 150 mg/L for Each 5ft of Water Depth**	**Vol. of Bleach Required in Fluid Ounces to Obtain 200 mg/L for Each 5ft of Water Depth**

Diameter of Well in Inches	Volume of Water per 5ft of Water Depth in Fluid Ounces	Vol. of Bleach Required in Fluid Ounces to Obtain 50 mg/L for Each 5ft of Water Depth	Vol. of Bleach Required in Fluid Ounces to Obtain 100 mg/L for Each 5ft of Water Depth	Vol. of Bleach Required in Fluid Ounces to Obtain 150 mg/L for Each 5ft of Water Depth	Vol. of Bleach Required in Fluid Ounces to Obtain 200 mg/L for Each 5ft of Water Depth
1 ½	40	0.04	0.08	0.12	0.16
2	69	0.07	0.14	0.21	0.28
2 ¼	138	0.14	0.28	0.41	0.55
4 ¼	491	0.49	1.0	1.5	2.0
5 ¼	749	0.75	1.5	2.2	3.0
6 ¼	1061	1.1	2.1	3.2	4.2
7 ¼	1428	1.4	2.9	4.3	5.7
8 ¼	1849	1.8	3.7	5.5	7.4
24	15,646	15.6	31.3	46.9	62.6
30	24,447	24.4	48.9	73.3	97.8
36	35,203	35.2	70.4	105.6	140.8

Reminder: When using ft and imperial fluid ounces, a person needs to divide the entire water column height in the well in ft by 5 and then multiply the result by the corresponding concentration found in the table to obtain the required dose.

Reminder: The formula used to calculate this table is based on common well casing diameters in inches. The calculated numbers have then been rounded.

Table 8-3: Amount (in Millilitres) of Bleach Required per 1 Metre of Well Water Depth to Create 50, 100, 150 and 200 mg/L of Free Chlorine where Bleach has Available Chlorine of 12% by Weight (Metric Measurements) (See Table 8-4 for the equivalent information provided in Imperial measurements.)

Diameter of Well in Centimetres	Volume of Water per Metre of Water Depth in Litres	Vol. of Bleach Required in mL to Obtain 50 mg/L for Each Metre of Water Depth	Vol. of Bleach Required in mL to Obtain 100 mg/L for Each Metre of Water Depth	Vol. of Bleach Required in mL to Obtain 150 mg/L for Each Metre of Water Depth	Vol. of Bleach Required in mL to Obtain 200 mg/L for Each Metre of Water Depth
3.8	1.1	0.5	0.9	1.4	1.9
5	2	0.8	1.6	2.5	3.3
6	3	1	2	3	4
11	9	4	8	11	15
13	14	6	12	17	23
16	20	8	16	25	33
18	27	11	22	33	44
21	34	14	29	43	57
61	292	122	243	365	486
76	456	190	380	570	760
91	656	273	547	820	1094

Reminder: The formula used to calculate this table is based on common well casing diameters in inches. The formula calculates the metric equivalent for diameter, litres per metre and then millilitres based on the initial industry standard diameter. The calculated numbers have then been rounded.

Table 8-4: Amount (in Fluid Ounces) of Bleach Required per 5ft of Well Water Depth to Create 50, 100, 150 and 200 mg/L of Free Chlorine where Bleach has Available Chlorine of 12% by Weight (Imperial Measurements) (See Table 8-3 for the equivalent information provided in metric measurements.)

Diameter of Well in Inches	Volume of Water per 5ft of Water Depth in Fluid Ounces	Vol. of Bleach Required in Fluid Ounces to Obtain 50 mg/L for Each 5ft of Water Depth	Vol. of Bleach Required in Fluid Ounces to Obtain 100 mg/L for Each 5ft of Water Depth	Vol. of Bleach Required in Fluid Ounces to Obtain 150 mg/L for Each 5ft of Water Depth	Vol. of Bleach Required in Fluid Ounces to Obtain 200 mg/L for Each 5ft of Water Depth
1 ½	40	0.02	0.03	0.05	0.07
2	69	0.03	0.06	0.09	0.12
2 ¼	138	0.06	0.11	0.17	0.23
4 ¼	491	0.20	0.41	0.61	0.82
5 ¼	749	0.31	0.62	0.94	1.2
6 ¼	1061	0.44	0.88	1.3	1.8
7 ¼	1428	0.59	1.2	1.8	2.4
8 ¼	1849	0.77	1.5	2.3	3.1
24	15,646	6.5	13.0	19.6	26.1
30	24,447	10.2	20.4	30.6	40.7
36	35,203	14.7	29.3	44.0	58.7

Reminder: When using ft and imperial fluid ounces, a person needs to divide the entire water column height in the well in ft by 5 and then multiply the result by the corresponding concentration found in the table to obtain the required dose.

Reminder: The formula used to calculate this table is based on common well casing diameters in inches. The calculated numbers have then been rounded.

Calculating Chlorine Solution Dose Amounts Using Calcium Hypchlorite Powder

The formula used to calculate this table is based on common well casing diameters in inches. The calculated numbers have then been rounded.

To Dose 1L of Water To 50 mg/L Of Free Chlorine

1 L = 1 kg or 1,000 g of water

To obtain the weight of a calcium hypochlorite powder at 65% available chlorine to create a dose of 50 mg/L (0.005%):

$(1\text{kg} \times 0.005\%) / 65\% = 0.00008\text{Kg}$
= 0.0008Kg (0.003 ounces) of calcium hypochlorite powder is needed to create a concentration of 50 mg/L of free chlorine in 1 L of water

To Dose 1L Of Water To 200 mg/L Of Free Chlorine

To obtain the weight of a calcium hypochlorite powder at 65% available chlorine to create a dose of 200 mg/L (0.02) %):

$(1\text{kg} \times 0.02\%) / 65\% = 0.0003\text{kg}$
= 0.0003 kg = 0.3 g (0.01 oz) of calcium hypochlorite powder is needed to create a concentration of 200 mg/L of free chlorine in 1 L of water

To Calculate Dose For The Column Of Well Water

Volume of Water in well = Weight of Water in Well × free chlorine residual desired [e.g., 50 mg/L (0.005%) or 200 mg/L (0.02 %)] divided by % of available chlorine (65 %).

Example

Use the above calculations and the previous well example where the 35 metre deep well has 600 L of water (600 L of water = 600 kg of water).

To obtain a concentration of 50 mg/L free chlorine using calcium hypochlorite powder with 65% available chlorine

$(600kg \times 0.005\%) / 65\% = 0.046kg = 46g\ (1.62oz)$

To obtain a concentration of 200 mg/L free chlorine using calcium hypochlorite powder with 65% available chlorine

$(600kg \times 0.02\%) / 65\% = 0.185kg = 185g\ (6.52oz)$

Tables To Calculate Dose Using Calcium Hypochlorite Powder

Table 8-5 and Table 8-6 provide the amount of calcium hypochlorite powder (at 65% available chlorine) needed to dose various diameters of wells that will create 50, 100, 150 or 200 mg/L of free chlorine per metre of water column. The calculations shown on the previous pages were used to derive Tables 8-5 and 8-6.

If a different amount of calcium hypochlorite powder is used, the calculations shown on pages 39 and 40 can be used to determine the amount required to dose the well.

Notes Regarding Table 8-5 and Table 8-6:

Reminder: The volume of calcium hypochlorite powder provided by the tables will have to be multiplied by the depth of the column of well water to determine the dose for the well. The calculations consider well volumes only and do not include water in the plumbing and the water used for mixing. For additional information, see the final note below.

Reminder: To dose the entire well column, the volume of calcium hypochlorite is obtained from Table 8-5 in grams and multiplied by the well water column height in metres.

Reminder: If the height of the water well column is measured in ft, divide the height of the well water column is divided by 5 and multiplied by the volume of calcium hypochlorite in ounces needed from Table 8-6.

Reminder: The tables provide the amounts of calcium hypochlorite needed to achieve the target under the ideal conditions of neutral pH (i.e., 7 pH units), no turbidity and no total dissolved solids. Additional calcium hypochlorite will be required if these conditions are not met. Test strips or other methods can be used to verify that the free chlorine residual achieved is no less than 50 mg/L and no more than 200 mg/L. Not meeting the required range can reduce the effectiveness of the treatment and in many cases requires the treatment to be repeated.

Reminder: The values in the tables do not account for the volume of any mixing water (typically 25 L or up to four to five times the volume of the well water column) or, if required, the volume of water in the plumbing (e.g., installing a pump in an existing well). It is important to consider these factors prior to putting the well into use because additional calcium hypochlorite will be needed to achieve the target dose concentration (see Table 8-7 or Table 8-8).

Table 8-5: Amount (in Grams) of Calcium Hypochlorite Powder Required per 1 Metre of Well Water Depth to Create 50, 100, 150 and 200 mg/L of Free Chlorine where Calcium Hypochlorite Powder has Available Chlorine of 65% by Weight (Metric Measurements). (See Table 8-6 for the equivalent information provided in Imperial measurements.)

Diameter of Well in Centimetres	Volume of Water per Metre of Water Depth in Litres	Dry Weight of Calcium Hypochlorite in Grams to Obtain 50 mg/L for Each Metre of Water Depth	Dry Weight of Calcium Hypochlorite in Grams to Obtain 100 mg/L for Each Metre of Water Depth	Dry Weight of Calcium Hypochlorite in Grams to Obtain 150 mg/L for Each Metre of Water Depth	Dry Weight of Calcium Hypochlorite in Grams to Obtain 200 mg/L for Each Metre of Water Depth
3.8	1	0.1	0.1	0.2	0.3
5	2	0.2	0.3	0.5	0.6
6	3	0.2	0.4	0.6	0.8
11	9	0.7	1.4	2.1	2.8
13	14	1.1	2.1	3.2	4.3
16	20	1.5	3.0	4.6	6.1
18	27	2.0	4.1	6.1	8.2
21	34	2.7	5.3	8.0	10.6
61	292	22.4	44.9	67.3	89.8
76	456	35.1	70.1	105.2	140.2
91	656	50.5	101.0	151.5	202.0

Reminder: The formula used to calculate this table is based on common well casing diameters in inches. The formula calculates the metric equivalent for diameter, litres per metre and then millilitres based on the initial industry standard diameter. The calculated numbers have then been rounded.

Table 8-6: Amount (in Ounces) of Calcium Hypochlorite Powder Required per 5 Feet of Well Water Depth to Create 50, 100, 150 and 200 mg/L of Free Chlorine where Calcium Hypochlorite Powder has Available Chlorine of 65% by Weight (Imperial Measurements). (See Table 8-5 for the equivalent information provided in metric measurements.)

Diameter of Well in Inches	Volume of Water per 5ft of Water Depth in Fluid Ounces	Dry Weight of Calcium Hypochlorite in Ounces to Obtain 50 mg/L for Each 5ft of Water Depth	Dry Weight of Calcium Hypochlorite in Ounces to Obtain 100 mg/L for Each 5ft of Water Depth	Dry Weight of Calcium Hypochlorite in Ounces to Obtain 150 mg/L for Each 5ft of Water Depth	Dry Weight of Calcium Hypochlorite in Ounces to Obtain 200 mg/L for Each 5ft of Water Depth
1 ½	33.8	0.003	0.005	0.008	0.010
2	69	0.005	0.011	0.016	0.021
2 ¼	138	0.01	0.02	0.03	0.04
4 ¼	491	0.04	0.08	0.11	0.15
5 ¼	749	0.06	0.12	0.17	0.23
6 ¼	1061	0.08	0.16	0.25	0.33
7 ¼	1428	0.11	0.22	0.33	0.44
8 ¼	1849	0.14	0.29	0.43	0.57
24	15,646	1.2	2.4	3.6	4.8
30	24,447	1.9	3.8	5.7	7.5
36	35,203	2.7	5.4	8.1	10.9

Reminder: When using ft and imperial fluid ounces, a person needs to divide the entire water column height in the well in ft by 5ft and then multiply the result by the corresponding concentration found in the table to obtain the required dose.

Reminder: The formula used to calculate this table is based on common well casing diameters in inches. The calculated numbers have then been rounded

Preparing Mixing Dose Above Ground Surface

Adding bleach or calcium hypochlorite directly to the well typically does not allow for a uniform dose of the well water column and makes it almost impossible to control the pH. To properly mix and if necessary control the pH, it is important to create the mixing dose in a bulk mixing or other container set on the ground surface. Therefore, extra water used to create the mixing dose has to be added to the water well column volume to provide the total water needed to be dosed.

If 25 Litres of water is used to mix the solution above the ground surface, then Table 8-7 or Table 8-8 provides the amount of unscented bleach and weight of calcium hypochlorite powder required to dose the 25 L (or 5 gal) of extra water used to mix the chlorine solution at 50, 100, 150 and 200 mg/L.

Best Management Practice – Mixing Four to Five times the Well Volume of Solution Above Ground Surface Prior to Dosing the Well

Where practical, a dosing solution of four to five times the water column volume of the well should be mixed in a bulk mixing container set on the ground surface and thoroughly mixed with the entire well column to account for:

- the standing well volume,
- the saturation of the adjacent formation, and
- if present, the saturation of the gravel pack.

Table 8-7: Amount of Bleach or Calcium Hypochlorite Powder Required to Dose 25 L of Water (Metric Measurements). (See Table 8-8 for the equivalent information provided in Imperial measurements.)

Bleach or Calcium Hypochlorite Powder Available Chlorine	Volume of Bleach (mL) or Weight of Calcium Hypochlorite Powder (g) Needed to Dose 25 L of Mixing Water to 50 mg/L	Volume of Bleach (mL) or Weight of Calcium Hypochlorite Powder (g) Needed to Dose 25 L of Mixing Water to 100 mg/L	Volume of Bleach (mL) or Weight of Calcium Hypochlorite Powder (g) Needed to Dose 25 L of Mixing Water to 150 mg/L	Volume of Bleach (mL) or Weight of Calcium Hypochlorite Powder (g) Needed to Dose 25 L of Mixing Water to 200 mg/L
Bleach with 5% Available Chlorine	25 ml	50 ml	75 ml	100 ml
Bleach with 12% Available Chlorine	10 ml	21 ml	31 ml	42 ml
Hypochlorite Powder with 65% Available Chlorine	2 g	4 g	6 g	8 g

Table 8-8: Amount of Bleach or Calcium Hypochlorite Required to Dose 5 Gal of Water (Imperial Measurements). (See Table 8-7 for the equivalent information provided in metric measurements.)

Bleach or Calcium Hypochlorite Powder Available Chlorine	Volume of Bleach (fl. oz.) or Calcium Hypochlorite Powder (oz.) Needed to Dose 5 Gal of Mixing Water to 50 mg/L	Volume of Bleach (fl. oz.) or Calcium Hypochlorite Powder (oz.) Needed to Dose 5 Gal of Mixing Water to 100 mg/L	Volume of Bleach (fl. oz.) or Calcium Hypochlorite Powder (oz.) Needed to Dose 5 Gal of Mixing Water to 150 mg/L	Volume of Bleach (fl. oz.) or Calcium Hypochlorite Powder (oz.) Needed to Dose 5 Gal of Mixing Water to 200 mg/L
Bleach with 5% Available Chlorine	0.8 fl. oz.	1.6 fl. oz.	2.4 fl. oz.	3.2 fl. oz.
Bleach with 12% Available Chlorine	0.3 fl. oz.	0.7 fl. oz.	1 fl. oz.	1.3 fl. oz.
Hypochlorite Powder with 65% Available Chlorine	0.06 oz	0.12 oz	0.18 oz	0.25 oz

Formula For pH Control During Chlorination

Mixing hypochlorite solutions will raise the pH and decrease the amount of effective hypochlorous acid available for disinfection. To control the pH, acids such as white vinegar can be added to the mixing water prior to adding the bleach. If the alkalinity of the water is measured or known then the following formula can be used:

Litres of White Vinegar = (Mixing Water Alkalinity ⁄ 100) × (Chlorine Dose ⁄ 500) × (Mixing Water Volume (Litres) ⁄ 100)

or

Gallon of White Vinegar = (Mixing Water Alkalinity ⁄ 100) × (Chlorine Dose ⁄ 500) × (Mixing Water Volume (Gallons) ⁄ 100)

Reminder: Alkalinity and chlorine dose are in milligrams per litre and volume is in litres and Imperial gallons.

Calculating The Volume Of Water For A Typical Horizontal Pipe (Waterline) From A Well To A Building

Reminder: Even though it is not a requirement of the *Wells regulation*, the plumbing in the building should be chlorinated along with the well to reduce pathogens in the entire water distribution system. The calculation used to determine the volume of the water well column can be used to determine the water in the different diameter plumbing lines within the building.

For A Typical Pipe Inside Diameter - 2.5 cm (1 inch)

Radius: 1.3 cm = 0.013 m
Area: 3.14 × 0.013 m × 0.013 m = 0.0005 m^2
Volume per 1 metre of pipe: = 1m × 0.0005 m^2
= 0.0005 m^3 = 0.5 Litres (0.2 imperial gallons)

Therefore, multiply length in metres of 3.2 cm (1 ¼ inch) horizontal pipe from plumbing to well by 0.5 L to obtain total volume of water in pipe.

For A Typical Pipe Inside Diameter - 3.2 cm(1 ¼ inch)

Radius: 1.6 cm = 0.016 m
Area: 3.14 × 0.016 m × 0.016 m = 0.0008 m^2
Volume per 1 metre of pipe: = 1m × 0.0008 m^2
= 0.0008 m^3 = 0.8 Litres (0.2 imperial gallons)

Therefore multiply length in metres of 3.2 cm (1 ¼ inch) horizontal pipe from plumbing to well by 0.8 L to obtain total volume of water in pipe.

Reminder: In calculating the amount of water in the plumbing, it is also important to add the volume of the hot water tank (typically noted on the tank's information) and any water storage tank. The additional water in the plumbing has to be added to the volume of the mixing water and the water well column.

Procedure For "Shock" Chlorination On Same Day After Completing The New Well's Structural Stage

The *Wells Regulation* - Unless exempt, on the day that the person constructing the well finishes the well's structural stage, the person must ensure the well is disinfected in accordance with the *Wells Regulation*.

To "shock" chlorinate a new well after the initial disinfection steps have taken place, the person constructing the well must dose the well to obtain a free chlorine concentration of not less than 50 mg/L and not more than 200 mg/L.

The following is only one suggested method of dosing the well with best practices that achieve the *Wells Regulation* disinfection requirements.

Suggested Method Of Dosing The Well Water

The steps for this recommended treatment approach are to:

Step 1: Calculate the volume of the well water in the well column.

Also, the mixing water should be added to the calculated volume of well water in the well column (e.g., an additional 25 L of water).

For example, the well has 375 L of water in the well column and the person will use 25 L of water to mix. The actual volume of water that needs to be dosed to not less than 50 mg/L and not more than 200 mg/L free chlorine is 375 + 25 = 400 L. These additional 25 L of clean water are the typical volume of water used in the mixing of the chlorine solution at the site. In other cases where the well and the aquifer space around the well need to be treated, the additional water may be five times the volume of the water well column.

Step 2: Determine the free chlorine concentration (e.g., 50, 100, 150 or 200 mg/L) within the required range needed to achieve the most effective treatment. It is also necessary to determine the type of hypochlorite product (e.g., bleach or calcium hypochlorite powder) that will be used in the treatment process. For better mixing results use fresh, unscented bleach.

Step 3: Calculate the amount of chlorine solution required to achieve the most effective treatment determined in step 2. To determine the dose needed to achieve 50, 100, 150 or 200 mg/L free chlorine in the well refer to Table 8-1 to Table 8-6. To determine an alternate concentration of free chlorine within the required range of 50 to 200 mg/L see the formulas in the "Calculating Chlorine Solution Dose Amounts Using Bleach" and "Calculating Chlorine Solution Dose Amounts Using Calcium Hypochlorite Powder" sections in this chapter.

Step 4: Place the calculated mixing water (e.g., 25 L) in a clean container set on the ground surface. The mixing water should be clean and potable. Combine the mixing water with the calculated amount of chlorine product in the container. When placed into the well, the calculated amount of chlorine product should be able to create the desired concentration of free chlorine in a single well volume.

Reminder: See "Best Management Practice – Mixing Large Volume of Clean and Potable Water, Vinegar and Chlorine Products Prior to Dosing the Well to Achieve Higher Concentrations of Hypochlorous Acid" (below).

Best Management Practice – Mix Large Volume of Clean and Potable Water, Vinegar and Chlorine Products Prior to Dosing the Well to Achieve Higher Concentrations of Hypochlorous Acid.

To ensure an effective dosing of the well and surrounding formation, a person performing disinfection should place a volume of four to five times the volume of the well water column of clean and potable water into a bulk mixing container set on the ground surface. To create the more effective hypochlorous acid, the pH of the mixing water should be lowered to 4.5 to 5.0 with NSF International approved acids before adding the chlorine product as described in the "pH levels" section in this chapter. An easy and effective acid is distilled white vinegar. A formula to achieve the most effective treatment using vinegar is shown in the "Formula for pH Control During Chlorination" section of this chapter.

Step 5: Prepare the chlorine solution by adding the calculated amount of liquid bleach or calcium hypochlorite powder to the mixing water into the container, taking into account pH levels and other factors that will impact the effectiveness of the dose.

Step 6: Pour this solution in the well and adequately mix to distribute the dose throughout the well column and let it stay undisturbed in the well for the required minimum of twelve (12) hours. Pouring should be done at a rate where the solution will not overflow out of the well. Pouring options to ensure the mixture is distributed throughout the entire well column include the following:

- The chlorine dose is poured into the well. A clean and spray-chlorinated drill string with a surge block or other development tool is moved up and down in the well column. Surge blocks are very effective in wells with well screens.
- Using an injection pump on a rig, the chlorine dose is pumped into the well. Then, the rig is used to surge the well with air. The surging technique lifts the column of water without discharging the water out of the well and drops it back down. The technique will mix the solution in the well column.
- The chlorine dose is poured into a larger diameter well while the well water is re-circulated with a pump, other than the water supply pump (i.e., discharging pumped water back into the well).
- The chlorine dose is placed into the bailer. The bailer is raised and lowered to agitate the well water.
- A clean and spray-chlorinated tremie pipe is installed near the bottom of the well. Then, the chlorine dose is injected into the well through the tremie pipe and allowed to discharge into the well. The tremie pipe is raised during the injection process to mix the dose throughout the entire well water column. This method can be used for both drilled and driven-point wells.
- A jetting tool is installed into the well. Then the chlorine dose is injected throughout the well water column using the jetting tool.

Reminder: It is important to conduct a free chlorine residual test shortly after dosing the well to ensure the free chlorine residual is within the required range and will likely be in the same range during the required testing period of at least 12 hours to not more than 24 hours after dosing the well. If the testing shortly after dosing shows a problem ($\leq$50 or $\geq$200 mg/L free chlorine) the person constructing the well can immediately:

- discharge or dispose of the chlorinated water in an approved manner (See "Handling Heavily Chlorinated Water Discharge" section in this chapter) and re-dose the well with another chlorine solution, or
- adjust the concentration of the free chlorine accordingly by either adding water or adding additional chlorine solution.

Best Management Practice – Ensuring Free Chlorine Residual Remains Above 50 mg/L for Entire Period

An initial dose that creates a concentration significantly higher than 50 mg/L of free chlorine should be used to ensure the free chlorine remains above 50 mg/L for the entire treatment period.

Best Management Practice – Ensuring Free Chlorine Residual Remains Above 50 mg/L for Entire Period

If the well is located in an area of high, naturally occurring arsenic, high concentrations of free chlorine could release arsenic into the well water after the treatment process. In this type of environment, a person constructing a well should

- not to exceed a dose of 100 mg/L free chlorine
- pump the water in the well 30 minutes after the initial dose has been placed in the well, and
- obtain a Director's written approval to use an alternate disinfection method (see the "Director's Written Approval to Use Alternate Method" section in this chapter for further information).

Best Mangement Practice – Using Field Kit Equipment to Test Water for Chemical Parameters

Field kit equipment should be used to test the water for total dissolved solids (TDS), turbidity and the other common parameters before dosing the well with a chlorine solution to determine if additional cleaning of the well or additional chlorine solution is needed.

Step 7: The treatment process has been completed and no further work is required as long as the person constructing the well ensures that the water will not be used for human consumption. If the person cannot ensure that the water will not be used for human consumption, then the person who undertakes the construction of the well must continue with the next steps.

Reminder: In highly fractured bedrock environments or highly permeable overburden environments, there is a potential for heavily chlorinated water to migrate from the well off-site to receptors (e.g., wells, rivers, streams). The person constructing the well should carefully calculate the volume and concentration of the chlorinated water to reduce the risk of off-site impacts and take all reasonable care to prevent the movement of chlorinated water off-site. It may be advisable to monitor off-site wells and have a contingency plan in case chlorinated water impairs off-site wells or other receptors.

If the Person Constructing the Well cannot ensure that the Water Will Not be Used for Human Consumption:

Step 8: Obtain a grab sample of the well water using clean sampling equipment and bottles at least 12 hours and not more than 24 hours after dosing the well. The grab sample must be tested for free chlorine residual. Testing can be done using simple test strips (Figure 8-4) similar to pH test strips shown in (Figure 8-2). If the free chlorine residual is within the required range (50-200 mg/L) see Step 11. If it is outside the range see Step 9.

Figure 8-4: Measuring Free Chlorine

Figure 8-4 provides an example of a free chlorine residual test strip (at the top of figure) and a comparison chart for various free chlorine residual concentrations. The test strip is placed into the chlorinated water solution and changes colour. The test strip's colour is matched to the comparison chart, which has the corresponding free chlorine residual concentration. In this case, a test strip for the 0 to 120 mg/L range shown at the top of Figure 8-4 was placed in the chlorinated water. The blue colour on the test strip matches a free chlorine residual of 30 mg/L on the 0 to 120 mg/L free chlorine residual comparison chart (shown in the middle of Figure 8-4). In this case, additional work needs to be done to bring the free chlorine in the water above 50 mg/L but not more than 200mg/L. A 0 to 750 mg/L free chlorine residual comparison chart is also shown in the bottom of Figure 8-4. The 0 to 750 mg/L free chlorine residual comparison chart also has similar test strips for testing free chlorine residual in water.

Step 9: Pump the well water out of the well until the well water has a free chlorine residual concentration of less than 1 mg/L if the test shows a free chlorine residual below 50 mg/L or more than 200 mg/L. The person undertaking the construction of the well can obtain a sample of the water in a clean sample container and use the test strips and comparison chart shown in Step 8 to determine the free chlorine concentration. See Step 10.

Reminder: See "Handling Heavily Chlorinated Water Discharge section" in this chapter for details on how to properly discharge or dispose of heavily chlorinated water.

Step 10: If step 9 applies (i.e., the free chlorine residual is outside of the required range), repeat steps 1 to 8 until the test shows the required free chlorine residual concentration range is not less than 50 and not more than 200 mg/L after 12 hours and not more than 24 hours after the water is re-dosed.

Step 11: Pump the well water out of the well until the well water has a free chlorine residual concentration of less than 1 mg/L after a test in accordance with Step 8 shows the free chlorine residual is within the target range (50-200 mg/L). The person constructing the well can obtain a sample of the water in a clean sample container and use the test strips and comparison chart shown in Figure 8-4 to determine the free chlorine residual.

Reminder: See the "Handling Heavily Chlorinated Water Discharge" section in this chapter for details on how to properly discharge or dispose of heavily chlorinated water.

Step 12: Before the well is used as a source of water for human consumption, the person undertaking construction of the well must ensure that the well purchaser is provided with a written record of the test results. An example of what a written record could look like is shown in Figure 8-5.

Step 13: Indicate on the well record that the well has been disinfected.

Download Figure 8-5: An Example Of A Written Record For Reporting Free Chlorine Residual Tests

Procedure For "Shock" Chlorination After Installing The Pump Or After Altering An Existing Well

The *Wells Regulation* - As soon as possible after the pumping equipment has been installed in a well or where a well has been altered (other than a minor alteration), unless exempt, the person doing the work must ensure that the well water is disinfected in accordance with the *Wells Regulation*.

This occurs after the debris removal and flushing have taken place (see Process of Disinfection in this chapter).

The following is only one suggested method of dosing the well with best practices that achieve the *Wells Regulation* disinfection requirements.

Suggested Method Of Dosing The Well Water

The steps for this recommended treatment approach are to:

Step 1: Store enough clean water to meet household and farm water needs for a minimum of 12 hours.

Step 2: Before treating the water system, remove or bypass any carbon filters, water softeners and other treatment units on the plumbing. Highly chlorinated water can damage treatment units including copper piping and fixtures. Therefore, it is important to follow the manufacturer's recommendations to ensure treatment systems are properly disinfected. Also it is important to ensure that the hot water tank's heat source is shut off.

Step 3: Follow Steps 1 to 8 from the "Procedure for "Shock" Chlorination on Same Day after Completing the New Well's Structural Stage" section in this chapter except for the following:

- During Step 1 and where the building's plumbing is to be chlorinated along with the water in the well, the person should:
  - estimate the volume of the water in the residential plumbing including the hot water and pressure tanks, the extra water for mixing (e.g., 25 L) and the volume of the well water column.
  - drain all of the water out of plumbing including the hot water tank prior to dosing.
- For Step 5 and where the building's plumbing and water in the well are to be chlorinated, the person altering the well or installing the pump can install a clean hose from an outdoor tap into the top of the well. The person can then dose the well and circulate the chlorinated water using the building's own plumbing to evenly distribute the treated water. In other cases where the well and the aquifer near the well need to be chlorinated, the other methods shown in Step 6 may be needed to distribute the chlorine dose.
- During Step 6, open all faucets (hot, cold, laundry and outside) in the plumbing and let the water run until the chlorine odour is detected. Since chlorinated water can damage the action in a septic system, chlorinated water should not be allowed into the building's sewage system.
- Unlike new well construction, the person altering an existing well or installing the pump is not allowed to stop at Step 7 even if the well will not be used for human consumption and must continue with the next steps.

Step 4: Follow Steps 9 to 13 from the "Procedure for "Shock" Chlorination on Same Day after Completing the New Well's Structural Stage" section in this chapter.

For steps that involve the discharge of chlorinated water, before turning on the pump after the 12-24 hour period, faucets or fixtures discharging to the septic tank systems should be temporarily diverted to an outside discharge point to avoid affecting the septic system.

Reminder: See "Handling Heavily Chlorinated Water Discharge" section in this chapter for details on how to properly discharge or and dispose of heavily chlorinated water.

Restricting Water Use During "Shock" Chlorination Period

The *Wells Regulation* - In between the dosing and testing outlined in the "Shock" Chlorination Steps section of the Plainly Stated section of this chapter and the disinfection requirements in the *Wells Regulation*, no person must disturb the well or use the water for any purpose.

Best Management Practice – Restricting Well Use and Sampling During Chlorination

During the “shock” chlorination period, the person constructing the well should communicate the following necessary precautions to the land owner, well purchaser and well samplers: [21]

- Well use must not take place to ensure that chlorine remains in the well in the target amounts and to meet the *Wells Regulation*.
- The well should not be sampled as the chemical and bacterial results could be biased. It is recommended that sampling not occur until testing shows there is no free chlorine residual associated with the well water.
- The well and area near the well should be vented if strong chlorine odours are detected.

During the shock chlorination period, a land owner, well purchaser and well samplers should also be notified of the following [22] :

- Do not drink the water and avoid all body contact with the water.
- Do not use chlorinated water for laundry, plants, fish tanks, etc.

Best Management Practice – Turn Off Pump During Disinfection Period

The pump should be shut off for the entire period of treatment to ensure the water is not mistakenly used by the well owner/well purchaser. Also, the water system should be set to bypass all water treatment units.

Special Circumstances To Allow Well Purchaser To Discharge Chlorinated Water

The *Wells Regulation* - The “shock” chlorination process after the initial dosing does not apply to an alteration of a well if all of the following conditions are met:

- The alteration involves the urgent replacement or repair of a pump that unexpectedly failed,
- No water supply is immediately available as an alternative to the water from the well, and
- The well purchaser provides written instructions to the person altering the well (e.g., repair or replacement of pump) to discontinue the disinfection process after the person altering the well initially doses the well to a concentration of not less than 50 mg/L and not more than 200 mg/L of free chlorine

In this case, the *Wells Regulation* requires the following:

- The well purchaser must ensure that, before the well water is used for any purpose, the water is pumped from the well until no odour of chlorine remains in the well water, and
- The person who undertakes the alteration must retain, for two years, the written instructions from the well purchaser to discontinue disinfection.

Best Management Practice - Using Test Strips or other Free Chlorine Residual Testing Equipment

To verify the chlorinated water has been removed from the well, inexpensive test strips as shown in Figure 8-4 or other types of free chlorine residual testing equipment should be used to test the water in the well.

Handling Heavy Chlorinated Water Discharge

Best Management Practice – Handling Heavily Chlorinated Water Discharge

Care should be taken to ensure that chlorinated well water is not pumped out in a quantity, concentration, or under conditions that may impair the quality of surface water or groundwater, or that cause, or may cause, adverse effects to the natural environment.

To handle water discharge, a hose should be used to direct the water to a safe area or location on the property where the chlorinated water will not cause damage.

When pumping discharge water, avoid [23] :

- pumping strong chlorine solutions onto land or landscape plants,
- running the water into any private sewage lines or a septic system as this may overload the leaching bed or cause the system to malfunction by killing the active bacteria in the tank,
- running water into a lake, stream or other body of water, and
- flushing for long periods as this may cause the water to flow onto a neighbouring property or roadways causing damage or flooding, and
- discharging into municipal sanitary or storm sewers without obtaining any necessary municipal or provincial approvals.

Highly chlorinated water can also be neutralized using chemicals such as sulfur dioxide, sodium bisulfite, sodium metabisulfite or sodium sulfite [24] . When using a neutralizer, the chlorinated water should be pumped from the well into a large storage tank on the ground surface. The neutralizer is then mixed with the chlorinated water in storage tank. Free Chlorine test strips (Figure 8-4) should be used to verify the chlorinated water has been neutralized.

No waste management or sewage approvals are required for discharging chlorinated water onto the owner's property. However, as indicated above, no person shall discharge the heavily chlorinated water that causes, or may cause, an adverse effect to the natural environment.

Best Management Practice – Handling Heavily Chlorinated Water Discharge (Continued)

A sewage works environmental compliance approval under the *Ontario Water Resources Act* will be required if the person discharges heavily chlorinated water off the well owner's property and the discharge capacity exceeds 10,000 litres per day. A guide to explain the sewage works process can be found on Ontario website.

If a safe discharge location is not available, the person constructing the well may need to properly store and transport the chlorinated water.

If a person wishes to haul heavily chlorinated water to a regulated waste disposal site, the person must have an approved waste management system (i.e., holds a valid environmental compliance approval) to carry the chlorinated water, must meet the requirements of the *General – Waste Management regulation* (*Regulation 347* as amended made under the *Environmental Protection Act*) and must dispose of the heavily chlorinated water at a licensed facility that is listed on the environmental compliance approval. A guide to explain approved waste management systems can be found on theOntario website.

Exemption From Disinfecting Flowing Wells

The *Wells Regulation* - The disinfection requirements in the *Wells Regulation* do not apply to minor alterations, test holes, dewatering wells and flowing wells.

Best Management Practice – Disinfecting Flowing Wells

In some situations it may be advisable to disinfect flowing wells. One of the following methods may be used:

- Extending casing above the static water level and following the disinfection procedure in this chapter to the extent possible.
- Sealing the top of the well with a packer and inserting a tube. The chlorine solution is injected through the tube. The dosing, contact time and discharge of the heavily chlorinated water should follow this chapter to the extent possible.
- Inserting a perforated container that has solid calcium hypochlorite tablets and allowing the tablets to dissolve near the bottom of a flowing well. The natural upflow will allow for the chlorinated water to disperse throughout the entire well water column. To reduce the loss of free chlorine during the process, the flow of water from the well should be restricted if possible.

Factors to consider when chlorinating flowing wells include:

- the potential for blow out due to improper construction,
- the potential for impairing water with discharging chlorinated water from the flowing well (see Handling Heavily Chlorinated Water Discharge Best Management Practice in this chapter), and

- the health and safety of on-site workers.

Replacing Pumping Equipment Above Or Adjucent To A Well

The *Wells Regulation* - Disinfection of the well is required during the replacement of a pump that is installed above or adjacent to a well or in a well pit if the well cap or well cover is removed during the installation.

Best Management Practice – Disinfecting all Equipment

To reduce the risk of contamination, the inside and outside of all new or used pumping equipment in or connected to a well should be disinfected.

Collection And Analysis Of Water Samples For Indicator Bacterial Parameters

In cases where wells have been disinfected, proper collection and analysis of well water samples after a "shock" chlorination treatment are a good way to determine if the chlorination treatment was successful.

When well water is tested for bacterial (as opposed to chemical) parameters, typically laboratories test for certain bacteria called indicator organisms or indicator bacteria. The presence of these indicators acts as an early warning signal. They indicate that the well water may not be safe for human consumption. The indicator bacteria usually show up in a test result if water has become contaminated by surface water runoff, soil bacteria, animal waste, sewage waste or some agricultural activities.

Best Management Practice – Sampling and Analyzing Well Water

All disinfection steps including development, cleaning, flushing, "shock" chlorination treatment and removal of heavily chlorinated water are designed to eliminate pathogens from the well water.

"Shock" chlorination treatment does not necessarily guarantee the water is bacteriologically safe for human consumption or bathing. For example, a source of contamination may be impairing the quality of the groundwater that the well has penetrated. Also, various chemical reactions between the chlorine solution and materials in the water (e.g., biofilm) may prevent the elimination of all pathogens in the water.

Therefore, the final step of well disinfection is to verify there are no indicator bacteria in the well water.

The person constructing the well, a Professional Engineer, a Professional Geoscientist or the well owner should sample the well water for bacterial indicator parameters. The first sample should occur 24 to 48 hours after the heavily chlorinated water has been pumped from the well, pumping equipment and plumbing. Two more samples should be taken one to three weeks apart.

All samples should be submitted to a public health laboratory or an accredited and licensed private laboratory. The laboratory should analyze the samples for bacterial indicator parameters to verify that the treatment has eliminated indicator bacteria from the well water.

Reminder: If the test results indicate that the well is not contaminated with indicator bacteria, it may still contain other contaminants such as chemicals. Tests for chemical, radiological or other bacterial parameters will verify that the well water is safe for human consumption and bathing.

Indicator Bacteria

There are two indicator organisms that Ontario public health laboratories will test for in a well water sample. These are Total coliform and Escherichia coli (E. coli).

Total Coliform

Total coliform refers to:

- a general family of bacteria that is commonly found in animal and human wastes, surface soils and vegetation,
- may indicate contamination of water with disease-causing organisms, and possible evidence of surface water runoff contamination in well water, and
- provides an early warning signal that there may be a problem with the water supply.

E. Coli

E. Coli are a group of bacteria that commonly live in the intestines of warm-blooded animals. The presence of E. Coli:

- indicates recent fecal contamination from sources such as human sewage or livestock waste.
- may indicate that there is a problem with the water supply.

Reminder: Do not use water containing total coliform or any E. Coli for drinking, making infant formula and juices, cooking, making ice, washing fruits or vegetables, brushing teeth, hand washing, bathing or showering unless it has been properly disinfected or treated.

Sampling And Analyzing Well Water

Table 8-9 outlines the roles of various groups involved in bacterial sampling and testing.

Table 8-9: Groups Involved in Bacteriological Sampling and Testing

Service	Contact If…	How to Locate
Public Health Unit	• Surface water, or human or animal waste is suspected to have entered a well. • A water sample bottle for indicator bacteria testing is needed. • Help in interpreting water quality sample results is needed.	• Local public health unit should be listed in the blue pages of the telephone book • Information is available at the Ministry of Health and Long-Term Care website. • Toll free INFOline: • In Toronto: • TTY: 1-800-387-5559
Public Health Lab	• A water sample bottle for indicator bacteria testing is needed. • Public Health Labs perform bacterial water testing free of charge	• Toll free INFOline: • In Toronto: • TTY:
Private Accredited Lab	• There are concerns about chemicals in a well • Private Labs test for bacterial and various chemical parameters	• For information about accredited laboratories, contact the Ministry of the Environment and Climate Change at
Licensed Well Contractor	• There are concerns that require a well to be upgraded • Can assist in sampling the well and submitting the sample to the laboratory	• Listings in the Yellow Pages (e.g., under the Water Well Drilling & Services heading) • A list of well contractors can be found at Ontario's website. • It is important to ensure that the well contractor is properly licensed to provide this service
Professional Geoscientists and Engineers Certified Engineering Technicians and Technologists	• Assistance with identifying sources of contamination and pathways is needed. • Can assist in sampling the well and submitting the sample to an accredited laboratory • Assessment and recommendations on a well are needed.	• Listings in the local Yellow Pages (e.g., under the Environmental Consultants heading) • Other listings may be available at: ◦ Professional Enginners Ontario website, ◦ Association of Professional Geoscientists of Ontario website ◦ Ontario Association of Certified Engineering Technicians and Technologists website.

Service	Contact If…	How to Locate
Ministry of the Environment and Climate Change (local area or district office)	• Surface water, or human or animal waste is suspected to have entered a well • Help is needed in interpreting water quality sample results or the *Wells Regulation*	• Ontario website

How To Collect Well Water Samples

The steps for collecting well water samples are to:

1. Obtain a clean and sterile sample bottle from the local public health unit, public laboratory or private laboratory along with the required paperwork.
2. Determine the location for taking the sample.
    - If it is a new well, a temporary clean pump and waterline may have to be installed into the well. As an alternative, a grab sample using clean sampling equipment will have to be lowered into the well.
    - If it is an existing well attached to established plumbing, in addition to the above, a person may be able to sample the water from a sampling tap at the pressure tank, kitchen or bathroom sink or at an outside faucet. These locations need to be accessible for sampling, clean, in frequent use, flow in a uniform stream and only hooked into cold, raw water (i.e., should not be taken from a combination hot/cold tap). Avoid taking samples where the tap leaks or is subject to splashing.
    - In some situations, the outside tap is a good location to take the sample, provided it is commonly used, clean and it is not hooked up to a hose at the time of sampling.
    - Aerators may impact the sample result. The test for indicator bacteria is to verify if the treatment on the well water worked. It is important that the aerator be removed from the tap if present.
3. If a tap is chosen, clean and disinfect the sampling location with alcohol wipes or a clean cloth soaked in a chlorine solution. Ensure the chlorine solution or alcohol is removed (e.g., air dries) from the tap before sampling.
4. If a pump is used in a new well or a tap is used in an existing well with established plumbing, flush the system at as high a rate as possible for at least 5 minutes at the sample location point to obtain fresh groundwater from the aquifer. The longer the flushing, the more likely the sample will represent the true groundwater quality because the water that has been stagnant in the plumbing and well column will have been flushed out.
5. Reduce the flow after at least 5 minutes of flushing.

    Reminder: In some cases, problems such as biofilm in the well are protecting bacteria that may be living in the well. If casing and water is removed from the well so that fresh groundwater from the aquifer is being delivered to the sample point, a person will miss any free swimming resident organisms. Sampling for coliform like organisms living in or on the side of the well with biofilm should be done only after the well has set idle for 8 to 12 hours. After this period, a volume of water equal to the volume in the plumbing within the building, the horizontal waterline to the well and the drop pipe in the well (pump out first) should be flushed to allow for the true casing and borehole water to be sampled.

6. Using protective and clean vinyl, latex or nitrole gloves, remove cap from sterile sample bottle and if possible do not set the cap on any surface.
7. Put the sample bottle under the flow of water and fill the water to no higher than the top of the sample bottle's label.

    Reminder: It is important to not let the water overflow, or not pour any water, out of the sample bottle as the laboratory has put a chemical (sodium thiosulfate preservative) into the bottle to inactivate chlorine and preserve the sample.

8. Remove the sample bottle from the flow area of the tap and seal it with the lid.

    Reminder: It is important to not touch the lid or interior of the cap as this may introduce bacteria and affect the sample results.

9. Place the sample bottle in a cold area such as a fridge or cooler with ice. Do not store the sample bottle in a freezer.
10. Complete the paperwork provided by the laboratory.
11. Submit the sample bottle and the paperwork to the drop off location specified on the paperwork within 24 hours after the sample of water was collected. Ensure the sample is placed in a cool area such as a cooler with ice during transportation to the drop off location.
12. If sample analysis reports no E. coli or total coliform bacteria, repeat the above 11 steps twice more with a 1 to 3 week interval between sample collections. If sample analysis reports E. coli or total coliforms see the section Interpretation of Laboratory Analysis below.

Interpretation Of Laboratory Analysis

The Ontario Drinking Water Quality Standards require that drinking water be free of total coliforms and E. coli [25] .

If the three test results report no E. coli or total coliform present, then the well water has been successfully disinfected.

If the test results show the presence of indicator organisms, it is important to take further action. The Public Health Unit can assist the well owner or the person constructing the well with an interpretation of the test results. Some options include:

- re-sampling the well to verify the initial sample results.
- sampling for various chemical or bacterial parameters. If the presence of indicator organisms were confirmed, the well owner should retain a Professional Geoscientist or Professional Engineer. The professional can
  - assess the hydrogeology around the well,
  - identify the source of contamination, and
  - provide recommendations to prevent it from accessing the well.
- consulting with a water treatment specialist to remove the contaminant from the drinking water.

Reminder: In cases where the Professional Geoscientist or Professional Engineer identifies a potential source of off-site contamination, it is important to contact and report the issue to the local Ministry of the Environment and Climate Change office (see resources at the end of this manual for Ministry office locations and telephone numbers) or the Ministry's Spills Action Centre at .

Reminder: The problem will not be resolved if water treatment is pursued without identifying and addressing the source of contamination.

The *Wells Regulation* - The well owner must abandon a well that is producing water with total coliforms, E. coli or other Ontario Drinking Water Quality parameters that exceed maximum acceptable concentrations found in Ontario Drinking Water Quality Standards (*Ontario Regulation 169/03*).

The well owner is exempt from this requirement if the well owner immediately seeks the advice of the local Medical Officer of Health (Public Health Unit), follows the directions of the local Medical Officer of Health and ensures that the measures taken are functional at all times. As another alternative the well owner can seek a written consent from the Director not to abandon the well

Reminder: See Chapter 14: Abandonment: When to Plug & Seal Wells for further information.

If the results show that the drinking water contains no significant evidence of bacterial contamination, then it is recommended that the water be tested at least three times per year. One of the three samples sent for testing should be taken in the spring.

Director's Written Approval To Use An Alternate Method

The *Wells Regulation* requirements for well disinfection using free chlorine are not required to be followed if the Director gives written approval for another method of disinfection and the approval method is properly followed by the person constructing the well. If the person constructing the well intends to use an alternate method of disinfection, then written approval must be received from the ministry prior to constructing or altering a well including the installation of a pump.

Where Does The Person Construcing The Well Have To Go To Seek A Written Approval From The Director?

If a well owner or a person constructing the well wishes to seek the written approval of the Director to use another method of disinfection the person constructing the new well or altering the existing well, including installing a pump, may contact the Wells Help Desk:

- In writing to Wells Help Desk, Environmental Monitoring and Reporting Branch of the Ministry of the Environment and Climate Change, 125 Resources Road, Toronto ON M8P 3V6;
- By telephone at (for Ontario residents only);
- By fax at: 416-235-5960; or
- By e-mail at: helpdesk@waterwellontario.ca

What Information Is Needed For a Written Consent?

The ministry assesses each case individually and on its merits. As a minimum, applicant's contacting the ministry for a written consent should provide a written request with the following information:

- The name of the individual(s)/entity that owns the well
- The location of the well
- An indication as to whether or not the well in question is new or an existing well
- The purpose of the well,

- The justification as to why the well needs to be disinfected using another method,
- An overview of the proposed alternate method,
- Written certification by the manufacturer or retailer that the alternate disinfection process will be effective in disinfecting the well, and
- Historical and current water quality information for both raw and treated samples of the water extracted from the well in question if applicable.

If well design, water quality or gas issues exist, a well owner or the person constructing the well may be required to retain a Professional Engineer or Professional Geoscientist who would have to prepare a scientific report showing the appropriate scientific rationale to support the application. The well owner or person constructing the well would have to submit the report along with the request for written approval to the Ministry for its consideration.

The request for written approval should be submitted to the Ministry along with any and all supporting documents such as a hydrogeological and/or a well design report. The person constructing the well and others should be cautioned that obtaining a written approval will not be an automatic process. The Ministry has to provide for the conservation, protection and management of Ontario's waters and for their efficient and sustainable use, to promote Ontario's long–term environmental, social and economic well–being.

Depending on the case, and as part of the Director's consideration, the Director may ask other regulators and interested parties to comment on the request.

The person constructing the well, the well owner and others should be cautioned that obtaining a written consent will not be an automatic process, since the Ministry has to provide for the conservation, protection and management of Ontario's waters and for their efficient and sustainable use, to promote Ontario's long-term environmental, social and economic well being.

The Director will review the request, supporting information, and other information generated from internal and external parties with an interest in the application.

Based on the information, the Ministry will contact the well owner in writing indicating the Director's decision.

Alternate Method When Arsenic Is Present

The Director recognizes that in parts of the Canadian Shield area of Ontario, elevated levels of naturally occurring arsenic can occur in igneous or metamorphic bedrock. In such circumstances, the high pH that may result from chlorination may cause arsenic to leach into groundwater and water supplies (see Chapter 4: Siting the Well for further information on identifying problems with groundwater). The Director will consider giving written approval in areas where elevated levels of arsenic may occur if a person follows "Best Management Practice - Alternate Chlorination Approach When Arsenic is Present."

Best Management Practice – Alternate Chlorination Approach When Arsenic is Present

The Director would consider giving advance written approval if the person disinfecting the well demonstrates that arsenic is either present or known to be present in the area and follows:

- the application process,
- all of the requirements for Well Disinfection in the *Wells Regulation* except that the concentration of the free chlorine is not less than 50 milligrams per litre and not more than 100 milligrams per litre and the free chlorine in the well is pumped after 30 minutes of chlorination, and
- the Bacterial Sampling Best Management Practice below.

Alternate Method When Person Cannot Maintain A 50 mg/L Free Chlorine Residula For At Least 12 Hours

The Director recognizes that in some bedrock wells, chlorinated water will move away from the well into the aquifer and the person can not maintain a free chlorine residual of at least 50 mg/L. The Director will consider giving written approval where the person has followed the Alternate Chlorination Approach When 50 mg/L of Free Chlorine cannot be Maintained for at Least 12 hours Best Management Practice.

Best Management Practice – Alternate Chlorination Approach when 50 mg/L of Free Chlorine Cannot be Maintained for at Least 12 hours

The Director would consider giving advance written approval if the person disinfecting the well demonstrates that s/he can not maintain a free chlorine residual of at least 50 mg/L over at least a 12 hour period, and follows:

- The application process
- All of the requirements for Well Disinfection in the *Wells Regulation* except that the concentration of the free chlorine residual after 12 hours can be less than 50 milligrams per litre
- The Bacterial Sampling best management practice below

Alternate Method - Bacterial Sampling

The following Bacterial Sampling best management practice is part of the alternate disinfection methods discussed above.

Best Management Practices – Bacterial Sampling

The person constructing the well should sample the well for total coliforms and E. coli bacteria one week after the heavily chlorinated water has been pumped from the well, pumping equipment and plumbing.

The person constructing the well should submit all samples to a public health laboratory or an accredited and licensed private laboratory. The laboratory must analyze the samples for bacterial indicator parameters.

The person constructing the well should ensure all laboratory findings and reports are delivered to the well owner and, where applicable, the well purchaser.

If the sample analysis shows indicator bacteria are not present the person constructing the well must obtain one more sample for total coliforms and E. coli bacteria analyses and the sample should be taken between one to two weeks after the initial sample.

The person constructing the well should submit all additional samples to a public health laboratory or an accredited and licensed private laboratory. The laboratory should analyze the samples for bacterial indicators.

The person constructing the well should ensure all additional laboratory findings and reports are delivered to the well owner and, where applicable, the well purchaser.

If indicator bacteria are present, the person constructing the well should provide the well owner, and where applicable, the well purchaser with the documentation that the well owner must:

- abandon a well that is producing water with total coliforms or E.coli,
- immediately seek the advice of the local Medical Officer of Health (Public Health Unit), follows the directions of the local Medical Officer of Health and ensures that the measures taken are functional at all times, or
- immediately seek written consent from the Director not to abandon the well

Reminder: See Chapter 14: Abandonment: When to Plug & Seal Wells for further information on the *Wells Regulation* requirements when the well is producing water that is not potable (e.g., total coliforms or E.coli are present).

Alternate Method When Petroleum Hydrocarbons, Solvents Or Other Contaminants Are Present

The Director recognizes that in areas contaminated with petroleum hydrocarbons, solvents or other contaminants, reactions with chlorinated water can create other chemicals which can be dangerous or hazardous.

Best Management Practice – Disinfecting when Petroleum Hydrocarbons, Solvents or other Contaminants are Present

The Director would consider giving advance written approval not to follow the disinfection requirements in the *Wells Regulation* for the time period that the contaminant is impairing the well water if a person constructing a well:

- follows the application process, and
- provides evidence (e.g., laboratory sample analysis reports and an interpretation of the reports) that the area and groundwater are contaminated with petroleum hydrocarbons, solvents or other contaminants.

9. Equipment Installation

Chapter Description

This chapter provides information, illustrations, advantages and disadvantages for the installation of pumps, caps, covers, vents and other equipment in or connected to wells. This chapter covers the requirements and exemptions for the installation of equipment in wells and provides information on the installation of equipment in wells completed above ground and in well pits.

Regulatory Requirements - Equipment Installation

Relevant Sections - The *Wells Regulation*

- Exemptions – Section 1.0.2
- Installation of Equipment – Sections 15.2 to 15.3
- Venting – Section 15.1
- Surface Drainage – Section 12.3
- Disinfection – Section 15
- Well Pits – Subsections 12(7) to 12(9), subsection 13(14) and Section 14.5

The Requirements - Plainly Stated - Installing Equipment

The *Wells Regulation* Provides Exemptions for the Following Activities Related to Equipment Installation

Exemptions for Equipment and Activities

Well licensing Requirements in the *Ontario Water Resources Act* and the requirements in the *Wells Regulation* do not apply to any of the following activities that are part of the construction of a well:

- Inspecting the well using equipment that is not left unattended in the well.
- Monitoring, sampling or testing the well using equipment that:
  - is not used to test the yield of the well or the aquifer, and is not left unattended in the well; or
  - is not used to test the yield of the well or the aquifer, and was previously installed in the well.
- Installing equipment for monitoring, sampling or testing a test hole or dewatering well, unless the:
  - installation of the equipment involves an alteration of the well, other than notching the top of the casing; or
  - equipment is used to test the yield of the well or the aquifer.

Reminder: See Chapter 3: Well Contractors & Well Technicians – Licences, Responsibilities & Exemptions for information on licensing for equipment installation activities that are not exempt from the well licensing requirements in the *Ontario Water Resources Act* and the requirements in the *Wells Regulation*.

The *Wells Regulation* Requires a Person Constructing a Well to Meet the Following, Unless an Exemption is Provided in This Section

Equipment in a Well

Any equipment installed in a well must be clean.

Reminder: All equipment installed in a well must not cause or have the potential to cause impairment to the water in the well or the groundwater as required under Subsection 30(1) of the *Ontario Water Resources Act*.

Connections to Drilled Wells

If a connection to the casing of a drilled well is made below the ground surface, a well seal or pitless adapter must be used and the connection must be made watertight.

Pitless units, which consist of a pitless adapter and casing, are also an acceptable method to connect pumping equipment to drilled wells.

A cutting torch must not be used to make an opening in the casing wall when installing a pitless adapter.

Connections to Wells Other than Drilled Wells

Any below ground connection to the casing of a well that is not a drilled well must be made watertight with durable bonding material.

Excavation beside the Casing

Any excavation created when making a below ground connection to the casing of a well must be filled with suitable sealant extending from the casing a minimum distance outward of 20cm (8 inches) and extending from the bottom of the excavation to within 20cm (8 inches) of the ground surface.

Venting- General

Unless exempt, when a new well is constructed by any method, the well must be vented to the outside atmosphere so that all gases can be safely dispersed.

Exemptions - General Venting Requirement

The above venting requirement does not apply to a:

- test hole, or
- well where the casing will be used to transmit water out of the well (e.g., a flowing well that does not have a pump).

Venting – Drilled Well with a Pump

Unless exempt, if a pump is installed in a drilled well, the following air vent requirements apply:

- An air vent must be installed with a minimum inside diameter of:
  - 0.3 cm, (0.11 inch) if the inside diameter of the casing is less than 12.7 cm (5 inches), or
  - 1.2 cm, (0.48 inch) if the inside diameter of the casing is 12.7 cm (5 inches) or more.
- The air vent must:
  - be long enough to extend above the covering of the well pit, if a well pit exists, or
  - extend above the ground surface at least 40 cm (16 inches) and at a height sufficient to prevent the entry of flood water from any anticipated flooding in the area, if no well pit exists, and
- The open end of the air vent must be shielded and screened to prevent the entry of any materials into the well.

Exemptions - Venting - Drilled Well with a Pump

The venting requirements for a drilled well installed with a pump do not apply to:

- a well with a well pit where there is no potential hazard from natural gas or any other gas, or

Venting a Well Pit

An air vent line must be installed on a new well in a new well pit and must extend above the cover of the well pit. The specific size and other requirements discussed in Venting – Drilled Well with a Pump in this Plainly Stated section do not apply.

Covering the Well

Dug or Bored

The top of the casing of a well that is constructed by digging or boring must be covered with a solid, watertight well cover, sufficient to prevent surface water and other foreign materials from entering into the well.

Drilled or Other Method

The top of the casing of a well that is constructed by any method other than digging or boring, such as drilling, must be sealed with a commercially manufactured vermin-proof well cap. This includes a properly installed and sealed sanitary well seal and a watertight and airtight well cap for a point well.

Alternative to a Well Cover

The cover or seal previously mentioned in the "Covering the Well" of the Plainly Stated section is not required if all of the following criteria are met:

- A floor has been constructed around or adjacent to the casing of the well,
- A pump is installed above or adjacent to the well,
- The top of the casing is shielded to prevent entry of any material that may impair the quality of the water in the well, and
- The casing of the well extends to at least 15 cm (6 inches) above the floor.

Reminder: The installation of a well cap or watertight well cover is considered a "minor alteration" to a well.

Disinfection

Unless exempt, as soon as possible after the construction or installation is complete, the water in the well must be dosed to a concentration of not less than 50 milligrams per litre and not more than 200 milligrams per litre of free chlorine.

Reminder: See Chapter 8: Well Disinfection for further information and *Wells Regulation* requirements on disinfection.

Reminder: The requirements for casing height for new wells are provided in the "Plainly Stated" section of Chapter 7: Completing the Well's Structure and the requirements for not reducing a casing above the ground surface are provided in the "Plainly Stated" section of Chapter 11: Maintenance & Repair.

Well Pits

In most circumstances, well pits are not allowed to be constructed on new or existing wells.

In certain circumstances, however, a person constructing a well may be allowed to finish the well with a well pit. The *Wells Regulation* provides options for the construction of permitted well pits depending on the type of equipment used to construct the well and the well's purpose.

The sections below in the Plainly Stated provide the *Wells Regulation* construction requirements for various well pit scenarios.

Permitted Well Pits for Water Supply Wells

A new well pit is permitted for a new well as long as the well is constructed with diamond drilling equipment in connection with mineral exploration.

Reminder: Diamond drilling equipment can be described as any drilling equipment that uses a diamond bit. Further clarification on the term "mineral exploration" is provided in Table 2-3 of Chapter 2: Definitions & Clarifications.

The requirements in the following sections must be met in order to install a new well pit on a well constructed with diamond drilling equipment in connection with mineral exploration.

Well Pit Walls (or Casing)

The walls of the new well pit are considered casing.

When a new well pit is constructed, the casing requirements found in Chapter 5: Constructing the Hole, Casing & Covering the Well, and Chapter 7: Completing the Well's Structure of this manual apply to the sides of a well pit. This includes the top of the sides of the well pit (i.e., casing) being at least 40 cm (16 inches) above the highest point on the ground surface within 3 m (10 ft) radially from the outside of the well pit's casing.

Surface drainage must not collect or pond in the vicinity of the well pit's casing

Well Pit Floor

The floor of the new well pit must be covered with at least 10 cm (4 inches) of suitable sealant that, when set to a solid state, will be capable of supporting the weight of a person.

Cover/Seal and Vent for a Well Located in a New Well Pit

The top of the casing of the well in the new well pit must be:

- at least 40 cm (16 inches) above the floor of the well pit, and
- sealed with a commercially manufactured sanitary seal. An air vent line must be provided from the seal to above the covering of the well pit.

Well Pit Cover

The top of the new well pit must be covered with a solid, watertight cover. The well pit cover must be:

- sufficiently sealed to prevent the entry of surface water and other foreign materials which would include insects and animals, and
- fastened in place in a manner that will make it difficult for children to remove the well pit cover.

Keeping the Well Pit Dry

The new well pit must be kept dry by means of a sump pump unless the water table is substantially lower than the floor of the well pit.

If the water table is substantially lower than the floor of the well pit, the new well pit may be kept dry by means of a drainage pipe from the well pit that:

- has a one-way valve to allow water to discharge from the pit but prevents surface water and other foreign materials, including insects and animals, from entering the well pit,
- passes through the layer of sealant, and
- allows water to discharge near the perimeter of the well pit.

For additional requirements that apply to permitted well pits, see the "Creating and Filling the Annular Space for a New Well Pit" and "Surface Drainage" sections in the Plainly Stated below.

Creating and Filling the Annular Space for a New Well Pit

The person constructing the well must ensure that the entire new well pit, from the bottom of the well pit to the ground surface, is constructed with a diameter that is at least 7.6 cm (3 inches) greater than the outside diameter of the well pit's walls (or casing).

Unless otherwise exempt, the person constructing the well must ensure that any annular space outside the new well pit's casing is filled, from the bottom of the well pit to the ground surface, with suitable sealant.

The sealant must provide the appropriate structural strength to support the weight of persons and vehicles that may move over the area after it is filled.

If the sealant contains cement:

- it must be allowed to set according to the manufacturer's specifications or for 12 hours, whichever is longer; and
- if after setting, the sealant has settled or subsided, it must be topped up to the ground surface.

Surface Drainage

The mounding of the ground surface beside the well must be done so that the surface drainage does not pond or collect in the vicinity of the well.

Reminder: Additional information on surface drainage can be found in Chapter 7: Completing the Well's Structure.

Relevant Sections - Additional Regulations Or Legislation

Ontario Regulation 164/99 as amended (Electrical Safety Code) made under the *Electricity Act, 1998*. S.O. 1998. Chapter 15, Schedule A;

Ontario Regulation 632/05 as amended (Confined Spaces) made under the *Occupational Health and Safety Act*, R.S.O. 1990, Chapter 0.1;

Ontario Regulation 213/91 as amended (Construction Projects) made under the *Occupational Health and Safety Act*, R.S.O. 1990, Chapter 0.1;

Relevant Guidance Documents

Fleming College. 2008. Manual for Continuing Education Course Safety (for Ontario Well Technicians).

WSC PAS-97(04) – "WSC Performance Standards and Recommended Installation Procedures for Sanitary Water Well Pitless Adapters, Pitless Units, and Well Caps." Water System Council, Washington DC. WSC website.

Well Record - Relevant Sections

Figure 9-1: Relevant Sections Of Well Record - Logistics

Well Tag No. - confirms that the well record is for the well being worked on.

Map of Well Location - helps find the well on the property.

Well Contractor and Well Technician Information - identifies the well contractor and provides contact information in the event that additional information is needed.

Figure 9-2: Relevant Sections Of Well Record - Construction

Well Casing:

- Important for clearance (i.e., well diameter) with down hole components (e.g., submersible pump)
- Identifies where casing ends or open hole starts/ends

Well Screen:

- Identifies if a well screen is present and its length, slot size and depth
- Helps ensure that the pump intake is installed above the top of the well screen

Water Details:

- Identifies location of groundwater intersected by the well
- Identifies gas that could affect pumping and cause problems or hazards in the water distribution system and well site
- Provides general remarks on the quality of water observed

Figure 9-3: Relevant Sections Of Well Record - Results Of Well Yield Testing

A. After Test Of Well Yield:
    - Indicates if there is particulate such as sand or silt in the well.
    - If particulate is present then take appropriate measures to remove it from the water distribution system and install appropriate pumping equipment for these conditions.
B. If Flowing Give Rate (see Chapter 12: Flowing Wells for additional details on equipment installation in flowing wells):
    - If flowing conditions are encountered during construction:
        - the person constructing the well must install an appropriate device to control the discharge of water.
        - the person installing equipment in the well should ensure that the device installed to control the discharge remains intact or is properly re-installed after equipment installation.
C. Recommended Pumping Rate:
    - Indicates recommended yield to determine appropriate pump size.
D. Well Production:
    - Do not use this value to size the pump as it may result in the well producing sand (e.g., well produces 29 GPM but only sand free at 7 GPM).
E. Drawdown/Recovery Columns:
    - Assists in the determination of the well's efficiency, appropriate pump size and intake elevation.
F. If Pumping Discontinued, Give Reasons:

- Indicates reason pumping did not last one hour. The reasons may indicate that the test may be suspect or the well may be low yielding.

G. Pump Intake Set At:
   - Indicates the elevation of the pump intake during the test.

H. Final Water Level:
   - Measured at the end of the pumping test and can be used to determine the appropriate pump size and location.

I. Recommended Pump Depth:
   - Values and locations are estimated by person constructing the well based on the results of the yield test.
   - The installer should consider all of the information from the well yield test when determining appropriate pump size, pump rate and intake location.

Key Concepts

What To Consider When Installing Equipment

It is important to consider the protection of health, safety and the environment when installing equipment. Unless exempt, the following requirements and considerations are relevant to the installation of equipment:

1. Anything that is put into the well must not impair the quality of the water,
2. The purpose for installing equipment (e.g., measuring),
3. The sanitary well seal, cover or cap must be properly secured on the top of the well to prevent the entry of surface water and other foreign materials,
4. Other than sample collection, contaminants should not enter or exit the well during any monitoring or sampling events,
5. Any space around the waterline through the side of the casing or through the top of the casing must be made watertight, and
6. In the case where a pump is installed in a dewatering well, for example, the final grade of the ground surface must allow for the proper height of casing and must not allow ponding of water in the vicinity of the well.

Best Management Practice – Installing Equipment

Anyone constructing (including installing equipment in) a well should:

- install new and undamaged parts, devices and materials in the well that are certified to meet the National Sanitation Foundation (NSF) International standards,
- install parts, devices and materials that are suitable for the particular type of environment and well,
- if necessary, clean the equipment with chlorinated water as suggested by AWWA C654 standard titled “Disinfection of Wells or the Michigan’s Water Well Disinfection Manual”, and
- ensure parts are installed to the manufacturers’ specifications.

Best Management Practice – Retain Licensed Persons to Perform Exempted Activities on Wells

To help further protect groundwater, exempted activities performed wells should be done:

- by properly qualified persons (e.g., licensed well technician or qualified professional) and
- to meet the requirements found in the *Wells Regulation* and best management practices found in this manual that deal with well construction and abandonment.

Connections To Wells

Connections may be required for a well to function properly. Connections can be made above and below the ground surface to accommodate waterlines or instrumentation to enter a well, for instance. Any connection must be made watertight. This reduces the risk of contamination of both the well and the aquifer.

Venting The Well

The purpose of the vent is to allow the well to breathe, which allows equalizing pressures (i.e., when water is drawn out, air goes in so the column of water is at atmospheric pressure at all times) and allow the safe venting of natural and other gases to the outside atmosphere.

Well Caps And Covers

Proper covering of the well prevents the entry of foreign materials into the groundwater.

Securing the well is a safeguard against unauthorized entry into the well, vandalism or tampering. Securing the well includes ensuring that the well cap, seal or cover is on properly and may include the use of a protective cover with locking cap, barriers or fences. For information on securing the well refer to Chapter 7: Completing the Well's Structure.

Casing Height & Mounding

The purpose of the minimum casing height is to prevent water from entering the well and to allow for venting. The purpose of mounding is to ensure that surface water runoff does not pond in the vicinity of the well and infiltrate into the well.

When installing or connecting equipment, the minimum casing height must be maintained and any mounding around the well that has been disturbed must be be restored to meet the drainage requirements found in the "Plainly Stated" section of this chapter. This does not apply if the equipment installation is exempt from the *Wells Regulation* (e.g., measuring the water level in a well using a water level meter) or if the equipment is installed in an exempted well (e.g., a pond).

Well Pits

A well pit is an enclosed structure, located at and below the ground surface that houses the top of the well and any associated pumping equipment. The top of the well casing extends out of the floor of the well pit.

A well pit is usually installed at or near the time of pump and associated equipment installation in the well.

The well pit can:

- protect the well from outside environmental conditions such as freezing of waterlines and the entry of surface water runoff and other foreign materials, and
- allow access to the well and pumping system from the ground surface for maintenance and repair.

Health And Safety Considerations - Trenches, Confined Spaces And Electrical

The safety manual from the well drilling continuing education course provides details regarding safety when excavating or working in trenches and confined spaces, along with precautions for working with or around electrical lines. This manual is available from Sir Sanford Fleming College (see the "Resources" section). It is recommended that these guidelines and the *Occupational Health and Safety Act* and its relevant regulations be reviewed prior to taking on any related tasks. Failure to be aware of the surroundings and follow appropriate safety procedures could result in serious injury or death.

Installing Pumping And Other Equipment

The *Wells Regulation* exempts any of the following activities that are part of the construction of a well:

- Inspecting the well using equipment that is not left unattended in the well.
- Monitoring, sampling or testing the well using equipment that:
  - is not used to test the yield of the well or the aquifer, and is not left unattended in the well; or
  - is not used to test the yield of the well or the aquifer, and was previously installed in the well.
- Installing equipment for monitoring, sampling or testing a test hole or dewatering well, unless:
  - the installation of the equipment involves an alteration of the well, other than notching the top of the casing; or
  - the equipment is used to test the yield of the well or the aquifer.

Any equipment installed in a well must be clean as required by the *Wells Regulation*.

Reminder: All equipment installed in a well must not cause or have the potential to cause impairment to the water in the well or the groundwater as required under subsection 30(1) of the *Ontario Water Resources Act*.

Reminder: For further information on what activities are exempt and what activities and wells require licensing, see Chapter 3: Well Contractors & Well Technicians – Licences, Responsibilities & Exemptions.

Best Management Practice – Installing Equipment

Anyone constructing a new well or working on an existing well should:

- install new parts, devices and materials in drinking water wells that are certified to meet the National Sanitation Foundation (NSF) International Standard 61 Drinking Water System Components – Health Effects [1] . Verify the components are certified by searching on the NSF 61 Products and Services Database and by looking for the NSF logo on the equipment.
- install parts, devices and materials that are suitable for the particular type of environment and well.
- clean the equipment with chlorinated water as suggested by AWWA C654 Disinfection of Wells standard or the Michigan's Water Well Disinfection Manual if necessary.
- ensure parts are installed to the manufacturer's specifications.

Best Management Practice – Have Well Record on Hand

The person installing the pump should have the well record and the information on Figure 9-1 to Figure 9-3 available any time pump work or other equipment installation is carried out on a well.

Pump Terms & Facts

A water well pump is designed to move water by a physical or mechanical action.

Pump
: includes associated pumping equipment.

Horsepower of the pump, outlet pressure in metres (or feet) of head, rate of water flow and inlet suction in metres (or feet) of head are key factors in selecting a pump. The head is considered the height the pump can raise a column of water at atmospheric pressure. Pressure is the amount of force acting on a unit area. Two units that may be used to describe pressure are psi (pounds force per square inch), and kPa (Kilopascals).

To select the type of pump, a system curve graph is created describing the relationship between the system's head and flow rate. Also a pump performance curve graph is created describing the relationship between the head versus the flow rate of the pump. By combining the two graphs, the pump type, horsepower and best operating system can be selected. Further information on pump selection may be found in Groundwater and Wells, Third Edition, 2007 [2] .

Table 9-1 provides common acronyms for flow rate and head parameters used in the installation of pumps and associated equipment. Table 9-2 provides pressure to head conversions used in pump selection.

Table 9-1: Acronyms For Head And Rate

Acronym	Term
m of head	Metres of head above pump intake
ft of head	Feet of Head above pump intake
TDH	Total Dynamic Head = Service pressure + pumping level + elevation + friction loss
LPH	Litres per Hour
LPM	Litres per Minute
GPH	Gallons per Hour
GPM	Gallons per Minute

Table 9-2: Pressure to Head Conversions Used in Pump Selection

Head Parameters	**PSI (pounds per square inch)**	**kPa (kilopascals)**
Conversion between units	1PSI = 6.9kPa	1kPa = 0.145PSI
Pressure of a column of water	= head in meters × 1.422 (1m of head = 1.422 PSI)	= head in meters × 9.807 (1m of head = 9.807 kPa)

Head Parameters	PSI (pounds per square inch)	kPa (kilopascals)
Pressure of a column of water	= head in feet × 0.432 (1ft of head = 0.432 PSI)	= head in feet × 2.989 (1ft of head = 2.989 kPa)
Metres of head of a column of water per unit of pressure	= pressure (PSI) × 0.703 (1 PSI = 0.703 m of head)	= pressure (kPa) × 0.102 (1kPa = 0.102 m of head)
Feet of head of a column of water per unit of pressure	= pressure (PSI) × 2.31 (1 PSI = 2.31ftof head)	= pressure (kPa) × 0.335 ("ahead of" 1kPa = 0.335ft of head)
Distance column of water raised per unit of pressure	1 PSI will raise a column of water 0.703 m (2.31 ft); regardless of the column's diameter.	1kPa will raise a column of water 0.1 m (0.335ft); regardless of the column's diameter.
Atmospheric Pressure and Head at sea level	14.7PSI [*] (14.7 PSI × 0.703 = 10.34 m of head) (14.7 PSI × 2.31 = 33.95 ft of head)	101.35kPa [*] (101.35kPa × 0.102 = 10.34 m of head) (101.35kPa × 0.335 = 33.95 ft of head)

The volume and weight of water are other considerations when selecting a pump. The following are a few common facts related to the volume and weight of water when installing a pump in a well:

- An Imperial gallon of fresh water weighs 4.5 kg (10 lbs).
- One litre of fresh water weighs 1 kg (2.2lbs).
- A cubic foot of water contains 0.028 cubic metres, 7.48 US gallons, or 6.24 Imperial gallons; and weighs 28.3 kg (62.4 lbs).
- A cubic metre of water contains 265 US gallons or 220 Imperial gallons.
- Volume of water per metre (or foot) in some wells:
  - 10.8 cm (4.25 inches) inside diameter contains 9.2 litres per metre (0.61 gallons per foot)
  - 13.3 cm (5.25 inches) inside diameter contains 13.9 litres per metre (0.94 gallons per foot)
  - 15.9 cm (6.25 inches) inside diameter contains 19.9 litres per metre (1.33 gallons per foot)
  - 0.91 m (3ft) diameter bored or dug well contains 656.1 litres per metre (44.0 gallons per foot)

Pump Types

The major pump types that are typically installed in wells are:

- Centrifugal pumps
- Jet pumps – shallow and deep
- Submersible pumps
- Variable speed constant pressure pumps
- Deep well turbine pumps
- Vertical turbine pumps

Table 9-3 provides details for the advantages, disadvantages, general capabilities and applicable well types for these pumps.

Table 9-3: Advantages, Disadvantages and Applicable Well Types for Various Pumps

Pump Type	Advantages	Disadvantages	Average Pumping Level Capability	Applicable Well Type(s)
Centrifugal Pump	• Generally produce high volumes of water • Depending on impeller design can also pass some small solids • Simple design – no jet is used • Great for irrigation and dewatering situations because of the volumes they can move	• Only effective to a 6 m (20ft) lift or less • Requires a pressure tank to maintain pressure	• Up to 6 m (20ft)	• Shallow Wells • Irrigation ponds • Dewatering (i.e., sump holes)

Pump Type	Advantages	Disadvantages	Average Pumping Level Capability	Applicable Well Type(s)
Jet Pump	• Low Cost • Higher volume capacity at low total head • Shallow well jet can be converted to deep well jet • Higher pressure can be acquired with multi-stage units • Can be offset from well • Easy to handle, service and very reliable because they have only one moving part, the impeller, which is directly connected to the motor • Require very little maintenance and have a reasonable operating life considering the workload • Deep well jet can be modified to adapt to low producing wells • Can be noisy and vibrate	• Cannot operate with air or gas in system • Difficult to prime if there is a leak in the line or if it is not level • Requires two lines for deep well jet • Easily damaged by particulate (sandy water) • As the vertical distance between the pump and water increases, the volume produced decreases • Limited depths of operation and discharge pressures • A control valve is needed on the outlet of the pump to provide a minimum back pressure of 138 kPa (20 PSI) for efficient jet operation • Requires a pressure tank to maintain pressure	• Shallow well jet pump up to 7.6 m (25ft) • Deep well jet pump up to 30 m (100ft) or deeper using multi-stage systems	• All well types
Submersible Pumps	• Has an excellent range in capacity and pressure because it pushes rather than draws water • Can be designed for large production well needs • Long lines cause few problems • Constant capacity • Can be used for shallow or deep well • Typically will not freeze • Can be installed in wells 10 cm (4 inches) or larger in diameter • More efficient than any other type of pump (i.e., high volumes and high pressure) with minimum horsepower • Silent running and low maintenance • Control box with electrical components located in building • Simple installation • Requires only one drop pipe (waterline)	• Loss of prime can cause damage to pump unless it is installed with low pressure protection devices (e.g. flow control valve, low water pressure switch and pump tech protection device) • Higher installation cost and initial investment • Not always easy to service and may be more expensive • Sand in water will cause pump parts to wear • If the pump intake screen becomes encrusted and flow is impaired the pump may be damaged due to cavitation • Well must be free from obstructions • May be subject to failure due to lightening strikes • Requires a pressure tank to maintain pressure	• Up to 305 m (1,000ft)	• Most drilled and larger diameter wells • Not for point wells • Typically not for narrow diameter wells constructed with diamond drilling equipment

Pump Type	Advantages	Disadvantages	Average Pumping Level Capability	Applicable Well Type(s)
Variable Speed Constant Pressure Pumps (Can be submersible or jet pumps)	• All the advantages of submersible pumps or jet pumps, depending on the type, as well as the following • No water pressure fluctuation issues and thus, provides water at a constant pressure • Extra electrical consumption savings • Saves space by using small pressure tanks • Easy servicing • User friendly control unit • Easy to size and set up • No separate starter box • In rare cases, an existing pumping system can be modified to make it a constant pressure pump	• All the disadvantages of submersible pumps or jet pumps, depending on the type, as well as the following • Sensors (depending on design) can be adversely affected by waters with high mineral content • In times of electrical outages there is very little water available as the pressure tanks are generally much smaller than on other systems	• Up to 305 m (1,000ft)	• Same as submersible pump or jet pumps, depending on the type
Vertical Turbine Pump	• High capacity and pressure	• Requires pump • Harder to service pump than submersible pump	• Up to 305 m (1,000ft)	• Large diameter drilled wells

Graphics Of Installed Pumps

The following graphics illustrate the installation layout for the following scenarios:

- Drilled Well with Shallow Jet Pump (Figure 9-4)
- Drilled Well with Deep Jet Pump (Figure 9-5)
- Drilled Well with Submersible Pump (Figure 9-6)
- Dug and Bored Wells with Shallow Jet Pump (Figure 9-7)
- Dug and Bored Wells with Submersible Pump (Figure 9-8)
- Driven Point Well with Shallow Well Pump (Figure 9-9)

The graphics show examples of installation only. They are not to scale. All dimensions and locations are for illustrative purposes only. Each of the wells shown Figure 9-4 through Figure 9-9 may encounter conditions that may require specialized design or construction. For example:

- flowing artesian conditions,
- presence of gas, or
- breathing (sucking & blowing) conditions where the well and aquifer formation are significantly affected by changes in atmospheric pressure

Reminder: The illustrations and graphics do not depict every circumstance and do not necessarily represent full compliance with other requirements found in the *Wells Regulation*.

Reminder: See the tables in the Tools Section at the end of this chapter for Drop Pipe and Down Hole Component information.

Reminder: All figures and diagrams are for illustrative purposes only and do not necessarily represent full compliance with other requirements found in the *Wells Regulation*.

Figure 9-4: Drilled Well With Shallow Jet Pump

Figure 9-4 is a cross-section diagram of a drilled well with a shallow jet pump. A casing extends from at least 40 centimetres (16 inches) above the ground surface into the hole. A vermin-proof well cap is located on top of the well. The electrical conduit opening, located on the bottom right of the vermin-proof cap, has been plugged. A well tag has been permanently affixed to the casing above the ground surface. The ground surface around the well has been mounded to prevent ponding of water in the vicinity of the well.

A cross-section of a building's basement is shown to the left of the drilled well. To the left of the well is a vertical wall and basement floor of the foundation. The vertical wall extends from above the ground surface to just below the frost line. At the bottom of the vertical wall, a horizontal floor extends from the bottom of the vertical wall to the left. In the subsurface and above the horizontal floor, a horizontal blue dotted line represents the frost line. The frost line extends from the vertical wall to the right side of the diagram.

A jet pump is shown in the diagram lying on top of the basement's floor and to the left of the vertical wall. A vertical output pipe extends vertically from the jet pump. A horizontal water pipe extends horizontally from the jet pump to the right through the vertical wall and through the side of the casing into the well. The horizontal pipe is sealed to the vertical wall with a waterproof sealing compound (e.g., hydraulic cement). The horizontal pipe is sealed to the casing with a pitless adapter. The horizontal pipe is located below the frost line.

A drop pipe (or riser pipe) is attached to the interior of the pitless adapter inside the well. The drop pipe extends below the static water level to a foot valve (or check valve). An intake screen is attached to the bottom of the foot valve.

An excavation is located around the casing. The excavation extends from the ground surface to just below the pitless adapter. The excavation is filled with suitable sealant. The suitable sealant extends a minimum 20 centimetres (8 inches) outward from the well casing and within minimum 20 centimetres (8 inches) from the top of the ground surface. Below the excavation, there is an annular seal between the outside of the casing and the side of the hole.

Reminder: This figure is not to scale, it is for illustrative purposes, and does not necessarily represent full compliance with other requirements found in the *Wells Regulation*. It does not depict every circumstance

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Figure 9-5: Drilled Well With Deep Jet Pump

Figure 9-5 is a cross-section diagram of a drilled well with a deep jet pump. A casing extends from at least 40 centimetres (16 inches) above the ground surface into the hole. A vermin-proof well cap is located on top of the well. The electrical conduit opening, located on the bottom left of the vermin-proof cap has been plugged. A well tag has been permanently affixed to the casing above the ground surface. The ground surface around the well has been mounded to prevent ponding of water in the vicinity of the well.

A cross-section of a building's basement is shown to the right of the drilled well. To the right of the well is a vertical wall of the basement's foundation. The vertical wall extends from above the ground surface to just below the frost line. At the bottom of the vertical wall, a horizontal floor extends from the bottom of the vertical wall to the right. In the subsurface and above the horizontal floor, a horizontal blue dotted line represents the frost line. The frost line extends from the vertical wall to the left side of the diagram.

A deep well setup jet pump is shown in the diagram lying on top of the basement's floor and to the right of the vertical wall. A vertical output pipe extends vertically from the jet pump. A horizontal pressure pipe extends horizontally from the jet pump to the left through the vertical wall and through the side of the casing into the well. The horizontal pressure pipe is sealed to the vertical wall with a waterproof sealing compound (e.g., hydraulic cement). The horizontal pressure pipe is sealed to the casing with a pitless adapter. The horizontal pressure pipe is located below the frost line. A horizontal suction pipe extends horizontally from the jet pump to the left through the vertical wall and through the side of the casing into the well. The horizontal suction pipe is sealed to the vertical wall with a waterproof sealing compound (e.g., hydraulic cement). The horizontal suction pipe is sealed to the casing with a pitless adapter. The horizontal suction pipe is located below the frost line.

A drop pressure pipe and suction pipe are attached to the interior of the pitless adapter inside the well. The drop pipes extend a minimum 3 metres below the static water level. A jet unit (venturi unit) is attached to the bottom of the two drop pipes. A foot valve (check valve is attached to the bottom of the jet unit (venturi unit). An intake screen is attached to the bottom of the foot valve.

An excavation is located around the casing. The excavation extends from the ground surface to just below the pitless adapter. The excavation is filled with suitable sealant. The suitable sealant extends a minimum 20 centimetres (8 inches) outward from the well casing and within minimum 20 centimetres (8 inches) from the top of the ground surface. Below the excavation, there is an annular seal between the outside of the casing and the side of the hole.

Reminder: This figure is not to scale, it is for illustrative purposes, and does not necessarily represent full compliance with other requirements found in the *Wells Regulation*. It does not depict every circumstance.

Figure 9-6: Drilled Well With Submersible Pump

Figure 9-6 is a cross-section diagram of a drilled well with a submersible pump. A casing extends from at least 40 centimetres (16 inches) above the ground surface into the hole. A vermin-proof well cap is located on top of the well. A well tag has been permanently affixed to the casing above the ground surface. The ground surface around the well has been mounded to prevent ponding of water in the vicinity of the well.

An excavation is located around the casing. The excavation extends from the ground surface to just below the pitless adapter. The excavation is filled with suitable sealant. The suitable sealant extends a minimum 20 centimetres (8 inches) outward from the well casing and within minimum 20 centimetres (8 inches) from the top of the ground surface. Below the excavation, there is an annular seal between the outside of the casing and the side of the hole.

A cross-section of a building's basement is shown to the right of the drilled well. To the right of the well is a vertical wall of the foundation. The vertical wall extends from above the ground surface to just below the frost line. At the bottom of the vertical wall, a horizontal floor extends from the bottom of the vertical wall to the right. In the subsurface and above the horizontal floor, a horizontal blue dotted line represents the frost line. The frost line extends from the vertical wall to the left side of the diagram.

A precharged pressure tank is shown in the diagram lying on top of the basement's floor and to the right of the vertical wall. A horizontal pressure pipe extends horizontally from the pressure tank to the left through the vertical wall and through the side of the casing into the well. The horizontal pressure pipe is sealed to the vertical wall with a waterproof sealing compound (e.g., hydraulic cement). The horizontal pressure pipe is sealed to the casing with a pitless adapter. The horizontal pressure pipe is located below the frost line.

A drop pipe is attached to the interior of the pitless adapter inside the well. The drop pipe extends below the static water level to a foot valve (or check valve). A submersible pump is attached to the bottom of the foot valve.

An electrical control box is attached to the interior of the vertical wall. An electrical cable extends vertically below the electrical control box. The electrical cable turns to the right and extends to the left through the vertical wall into the lower portion of the excavation around the well. The electrical cable turns upward into an electrical conduit. The electrical cable and conduit extend upward into the bottom of the vermin-proof well cap. The electrical cable extends through the well cap and turns downward into the well. The electrical cable extends downward in the well and attaches to the submersible pump.

Reminder: This figure is not to scale, it is for illustrative purposes, and does not necessarily represent full compliance with other requirements found in the *Wells Regulation*. It does not depict every circumstance.

Figure 9-7: Dug And Bored Wells With Concrete Casing And A Shallow Lift Pump

Figure 9-7 is a cross-section diagram of a dug or bored wells with concrete casing and a shallow lift pump. A casing extends from at least 40 centimetres (16 inches) above the ground surface into the hole. There are watertight joints between sections of casing. A solid, watertight well cover is located on top of the well. A well tag has been permanently affixed to the casing above the ground surface. The ground surface around the well has been mounded to prevent ponding of water in the vicinity of the well.

An excavation is located around the casing. The excavation extends from the ground surface to just below the pitless adapter. The excavation is filled with suitable sealant. The suitable sealant extends a minimum 20 centimetres (8 inches) outward from the well casing and within minimum 20 centimetres (8 inches) from the top of the ground surface. Below the excavation, there is an annular seal between the outside of the casing and the side of the hole.

A cross-section of a building's basement is shown to the right of the dug (or bored) well. To the right of the well is a vertical wall of the basement. The vertical wall extends from above the ground surface to just below the frost line. At the bottom of the vertical wall, a horizontal floor extends from the bottom of the vertical wall to the right. In the subsurface and above the horizontal floor, a horizontal blue dotted line represents the frost line. The frost line extends from the vertical wall to the left side of the diagram.

A jet pump is shown in the diagram lying on top of the basement's floor and to the right of the vertical wall. A vertical output pipe extends vertically from the jet pump. A horizontal pressure pipe extends horizontally from the jet pump to the left through the vertical wall and through the side of the casing into the well. The horizontal pipe is sealed to the vertical wall with a waterproof sealing compound (e.g., hydraulic cement). The horizontal pipe is sealed to the casing with a durable sealing material, link seal or pitless adapter. The horizontal pipe is located below the frost line.

A drop pipe (or riser pipe) is attached to the interior of the pitless adapter or horizontal pipe inside the well. The drop pipe extends below the static water level to a foot valve (or check valve). An intake screen is attached to the bottom of the foot valve.

Reminder: This figure is not to scale, it is for illustrative purposes, and does not necessarily represent full compliance with other requirements found in the *Wells Regulation*. It does not depict every circumstance.

Reminder: Larger diameter wells must not be entered as they are dangerous unless adequate safety precautions are taken using *Confined Spaces Regulation 632/05* under the *Occupational Health and Safety Act*.

Figure 9-8: Dug And Bored Wells With Concrete Casing And A Submersible Pump

Figure 9-8 is a cross-section diagram of a dug or bored wells with concrete casing and a submersible pump. A casing extends from at least 40 centimetres (16 inches) above the ground surface into the hole. The ground surface around the well casing has been mounded. There are watertight joints between sections of casing. A solid, watertight well cover is located on top of the well. A well tag has been permanently affixed to the casing above the ground surface. The ground surface around the well has been mounded to prevent ponding of water in the vicinity of the well.

An excavation is located around the casing. The excavation extends from the ground surface to just below the pitless adapter. The excavation is filled with suitable sealant. The suitable sealant extends a minimum 20 centimetres (8 inches) outward from the well casing and within minimum 20 centimetres (8 inches) from the top of the ground surface. Below the excavation, there is an annular seal between the outside of the casing and the side of the hole.

A cross-section of a building's basement is shown to the right of the dug (or bored) well. To the right of the well is a vertical wall of the basement. The vertical wall extends from above the ground surface to just below the frost line. At the bottom of the vertical wall, a horizontal floor extends from the bottom of the vertical wall to the right. In the subsurface and above the horizontal floor, a horizontal blue dotted line represents the frost line. The frost line extends from the vertical wall to the left side of the diagram.

A precharged pressure tank is shown in the diagram lying on top of the basement's floor and to the right of the vertical wall. A horizontal pressure pipe extends horizontally from the pressure tank to the left through the vertical wall and through the side of the casing into the well. The horizontal pressure pipe is sealed to the vertical wall with a waterproof sealing compound (e.g., hydraulic cement). The horizontal pipe is sealed to the casing with a durable sealing material, link seal or pitless adapter. The horizontal pressure pipe is located below the frost line.

A drop pipe is attached to the interior of the pitless adapter inside the well. The drop pipe extends below the static water level to a foot valve (or check valve). A submersible pump is attached to the bottom of the foot valve.

An electrical control box is attached to the interior of the vertical wall of the basement. An electrical cable extends vertically below the electrical control box. The electrical cable turns to the right and extends to the left through the vertical wall into the lower portion of the excavation around and the casing of the well. The electrical cable is sealed to the vertical wall with a waterproof sealing compound. The electrical cable extends downward in the well and attaches to the submersible pump.

Reminder: This figure is not to scale, it is for illustrative purposes, and does not necessarily represent full compliance with other requirements found in the *Wells Regulation*. It does not depict every circumstance.

Reminder: Larger Diameter wells must not be entered as they are dangerous unless adequate safety precautions are taken using *Confined Spaces Regulation 632/05* under the *Occupational Health and Safety Act*.

Reminder: The connection for the horizontal and vertical pipes shown would be supported by using a pitless adapter and supporting steel bracket anchored to the inside of the casing.

Figure 9-9: Driven Point Well With Shallow Lift Pump

Figure 9-9 is a cross-section diagram of a driven point well with a shallow lift pump. A casing extends from at least 40 centimetres (16 inches) above the ground surface into the hole. An air tight well cap is located on top of the well. The electrical conduit opening, located on the bottom right of the air tight well cap has been plugged. A well tag has been permanently affixed to the casing above the ground surface.

An excavation is located around the casing. The excavation extends from the ground surface to just below the pitless adapter. The excavation is filled with suitable sealant. The suitable sealant extends a minimum 20 centimetres (8 inches) outward from the well casing and within minimum 20 centimetres (8 inches) from the top of the ground surface. Below the excavation, there is an annular seal between the outside of the casing and the side of the hole.

A cross-section of a building's basement is shown to the left of the driven point well. To the left of the well is a vertical wall of the foundation. The vertical wall extends from above the ground surface to just below the frost line. At the bottom of the vertical wall, a

horizontal floor extends from the bottom of the vertical wall to the left. In the subsurface and above the horizontal floor, a horizontal blue dotted line represents the frost line. The frost line extends from the vertical wall to the right side of the diagram.

A shallow pump is shown in the diagram lying on top of the basement's floor and to the left of the vertical wall. A vertical output pipe extends vertically from the shallow pump. A horizontal water pipe extends horizontally from the shallow pump to the right through the vertical wall and through the side of the casing into the well. The horizontal pipe is sealed to the vertical wall with a waterproof sealing compound (e.g., hydraulic cement). The horizontal pipe is sealed to the casing at a "T" joint connection. The horizontal pipe is located below the frost line.

Reminder: Conditions and considerations for using a shallow well lift pump in a driven point well are as follows:

- Because of the small diameter of the well, this is generally the only type of pump that is suitable but a jet pump may also work.
- For new point wells constructed after December 31, 2007, a T-connection is made below the ground surface with the waterline (lateral pipe) attaching to the well casing.
- The new point well also will have an air tight well cap.
- The entire assembly must be airtight in order for the pump to maintain a vacuum in the entire well and waterline.
- The T-configuration allows access to the well and, if necessary, allows access to conduct maintenance on the well such as shock chlorination.
- The design of the point well should be able to withstand freezing and thawing.

Reminder: This figure is not to scale, it is for illustrative purposes, and does not necessarily represent full compliance with other requirements found in the *Wells Regulation*. It does not depict every circumstance.

Reminder: This set up is similar for jetted wells attached to a shallow well pump.

Below Ground Connections To Wells

Drilled Wells

The *Wells Regulation* - When making below ground connections to the casing of a drilled well, the person constructing the well must use a well seal or pitless adapter (including pitless units) and the connection must be watertight.

Pitless units or pitless adapters allow lateral pipes (i.e., waterlines) outside a drilled well casing to connect to drop pipes (waterlines) inside the well.

Reminder: A drop pipe usually extends from the connection at the pitless adapter to the pump or intake portion of the pumping equipment inside the well.

Pitless Adapters

A drop pipe usually extends from the connection at the pitless adapter to the pump or intake portion of the pumping equipment inside the well.

- connects downhole pumping equipment to piping in the trench, and
- allows the downhole pumping equipment to be easily removed while standing at the ground surface.

The size and number of holes through the casing depends on the design of the pitless adapter and pump equipment.

To ensure that the connection is watertight, it is necessary that person installing the pitless adapter follow the manufacturer's specifications and ensure that the adapter being installed is appropriate for the environment and the well design (e.g., casing size).

The *Wells Regulation* - The person constructing the well must not use a cutting torch to make an opening in the casing wall to accommodate a pitless adapter.

A cutting torch creates an opening that is too irregular to be made watertight.

Best Management Practice – Preparing to Install Pitless Adapter

Before installing the pitless adapter, the person installing equipment in the well should cut the hole in the casing wall with a hole saw and should remove metal burs along the open hole's edges to ensure that the pitless adapter creates a watertight fit to the casing.

A cordless drill helps eliminate the possibility of electrocution.

Figure 9-10: Pitless Adapter

Figure 9-11: Pitless Adapter Installed

Pitless Units

A pitless unit is a commercially manufactured piece of well casing with a pitless adapter already installed through the wall of the unit. It is primarily designed to make a watertight connection on top of the well casing.

Typically, a person installing a pitless unit will cut the top of well casing below the frost level. The pitless unit is then installed onto the top of the well casing by either welding or using a special clamp device.

To ensure that the connection is watertight to the well, it is important that persons installing pitless units follow manufacturer's specifications and ensure that the unit being installed is appropriate for the environment and the well design (e.g., casing size).

Figure 9-12: Cross-Section Of Pitless Unit

Figure 9-12 is a cross-section diagram of a pitless unit. The pitless unit is shown as a vertical pipe. A vermin-proof well cap is affixed to the top of the pitless unit. Below the vermin-proof cap and on the left side of the pitless unit, an air vent extends out of the pitless unit. Below the cap and on the right side of the pitless unit, an electrical conduit opening has been affixed to the exterior of the pitless unit to allow an electrical cable to enter into the well. The bottom of the pitless unit is attached to a casing using a watertight welded or threaded joint.

In the interior of the pitless unit, there is a vertical pull pipe that extends from the top of the pitless unit to a guide plate. To the left of the pull pipe an adjustable rod extends from the top of the pitless unit to the guide plate. A safety clip is attached to the top of the guide plate and pull pipe. The safety clip holds adjustable rod to guide plates when pulling the pump. A horizontal connection extends through the right side of the pitless unit from the guide plate. A standard neoprene O-ring seals the interior of the pitless unit around the horizontal connection. A drop pipe extends below the guide plate to the pump.

An electrical cable extends through the electrical conduit opening and into the pitless unit. The electrical cable extends downward through the pitless unit and well to the submersible pump.

Figure 9-13: Photographs Of Pitless Units

Best Management Practice – Installation of Pitless Adapters and Pitless Units

The person installing the equipment in the well should review and follow the standards and recommendations found in the Water Systems Council brochure titled WSC Performance Standards and Recommended Installation Procedures for Sanitary Water Well Pitless Adapters, Pitless Units, and Well Caps [3] , to assist in the proper installation of pitless units or pitless adapters.

The brochure is available at the Water System Council website.

Best Management Practice – Connecting Waterlines above the Ground Surface in a Drilled Well

If the person cuts a hole in a drilled well casing above the ground surface, the person should ensure that, at all times, the connection to the casing is watertight.

Sanitary Wells Seals

Sanitary well seals are primarily designed to create a watertight seal where the waterlines, air vents and electrical lines extend through the top of the well casing.

A sanitary well seal consists of a neoprene gasket between two steel plates. When the two plates are tightened together, the neoprene gasket expands, which seals waterlines, air vents, electrical lines and the casing.

When installing a sanitary well seal, it is necessary to follow the manufacturer's specifications to ensure that the connection is watertight and the appropriate seal is installed for the environment and the well design.

Figure 9-14: Sanitary Well Seal

The photograph shows an example of one kind of sanitary well seal. In this case, a blue steel plate is underlain by a black neoprene gasket. The gasket is underlain by another blue steel plate. One waterline can pass through the centre of the well seal. An air vent can be threaded onto the seal on the left side of the well seal. The red plug can be removed on the right side of the well seal to allow for an electrical line or other equipment through the well seal. By tightening the four steel bolts on top of the well seal, the two plates are tightened together expanding the neoprene gasket. The squeezed gasket seals the waterline, electrical line and the casing. The well seal is typically found at the top of the well casing. Other sanitary well seals have two holes for two waterline installations used in jet pumps.

Other Wells (e.g.,Dug And Bored Wells)

The *Wells Regulation* - When making a below ground connection to a well casing of a well other than a drilled well (e.g., constructed by boring, digging or augering equipment), the person constructing the well must make the connection watertight with a durable bonding material.

Any bonding material must be durable and adhere to the side of the casing and the waterline. Also, the bonding material must not impair the water quality.

Large diameter corrugated conduits or other pipe used to protect waterlines in trenches should not extend through the well casing. Only properly connected and sealed waterlines and electrical lines should extend through the casing.

It is important to know and follow the manufacturers' specifications for bonding material and installation of waterlines through the well casing (e.g., fiberglass, galvanized and concrete).

Best Management Practice – Waterline Connection through Concrete Casing

A concrete tile pitless adapter should be installed when a connection to a waterline is made through the side of a concrete casing.

As an alternative, a steel supporting bracket can be used on the inside of the well casing. The bracket will attach to the pitless adapter and allow the lateral pipe to extend through the casing and into the well. The horizontal pipe connection to the casing must be sealed with hydraulic cement or other durable bonding material that will not impair the water quality.

Reminder: Hydraulic cement looks like other cement and is used to stop water leaks through cracks and faults in concrete. Tape should be used to hold the cement in the connection area while it sets (cures).

Best Management Practice – Connecting Waterlines above the Ground Surface in a Well that is Not a Drilled Well

If the person cuts a hole into a casing above the ground surface of a well that is not a drilled well, the person should ensure that, at all times, the connection to the casing is watertight.

Installing Suitable Sealant Into Trench

To install a waterline and electrical wire from the well to the building's plumbing and electrical box, a trench is typically excavated from the well to the building. The trench will expose the side of the well. The depth of the trench is typically below the frost line to minimize the risk that the horizontal waterline from the well to the building's plumbing will freeze.

The *Wells Regulation* - When making a below ground connection to the casing of a well, the person constructing the well must fill any outside excavation with suitable sealant extending from the casing a minimum distance outward of 20cm (8 inches) and extending from the bottom of the excavation to within 20cm (8 inches) of the ground surface.

The person excavating the trench should consider the direction of the trench and the proximity to potential sources of contamination as the trench can act as a preferential pathway for contaminants.

Best Management Practice – Sealing the Excavation

It is important to consider the direction of the trench and the proximity to potential sources of contamination as the trench can act as a pathway for contaminants to migrate to the well site or building.

If suitable sealant has been installed to a horizontal distance that is greater than 20cm (8 inches) from the well casing (during the filling of the well's annular space), then the trench should be backfilled with suitable sealant from the outside of the well casing to at least the same distance as the original sealant.

When backfilling the remainder of the trench, the person installing the equipment should:

- place fully hydrated bentonite berms at set intervals at the bottom of the trench and over the top of the waterlines and electrical wires to help minimize horizontal movement of water and contaminants along the trench, and
- backfill the trench with clean soil that can withstand the weight of persons, animals and vehicles and will not promote the movement of water

If a larger diameter pipe is used to house the waterline and electrical wires from the well to a structure, the person installing the equipment should:

- stop the larger diameter pipe before the outside of the building and before the trench's sealant at the well to prevent surface water and foreign materials from entering the well site or building,
- ensure the larger diameter pipe is not perforated and is strong enough to withstand corrosion and the weight of the overlying materials, and
- take adequate precautions to prevent water or foreign material from entering the larger diameter pipe and from being directed toward any building, foundation or the well.

Venting The Well

The purpose of the air vent is to allow the well to breathe, which allows equalizing pressures (i.e., when water is drawn out, air goes in so the column of water remains at atmospheric pressure at all times) and the venting of natural gases.

Venting After New Well Construction

The *Wells Regulation* - When constructing a new well, the well must be vented to the outside atmosphere in a manner that will safely disperse all gases. This requirement does not apply to a:

- test hole, or
- well where the casing will be used to transmit water out of the well (e.g., driven point well).

Reminder: Flowing wells are not exempt from the regulatory requirement for venting unless the casing is used in some form to transmit water out of the well or the well is a test hole. A mechanical or inflatable packer with an air release valve and air vacuum relief valve may be installed to vent the well to allow air into and out of the well during pumping. See Chapter 12: Flowing Wells for further information.

Venting During Pump Installation In Drilled Wells

The *Wells Regulation* - Unless exempt, if a pump is installed in a drilled well, the person constructing the well must install an air vent on the well and meet the following requirements:

- An air vent must have a minimum inside diameter of:
  - 0.3 cm (0.12 inch) for a well casing that has an inside diameter ≤ 12.7 cm (5 inches), or
  - 1.2 cm (0.47 inch) for a well casing that has an inside diameter ≥ 12.7 cm (5 inches)
- In an area where there is potential for flooding, the air vent on a well must extend above the maximum anticipated flooding level and not less than 40 cm (16 inches) above the ground surface.
- On a drilled well in a well pit, the air vent may have a sufficient length to extend above the covering of the well pit.
- The open end of the air vent must be shielded and screened to prevent the entry of foreign materials (e.g., insects) into the well.

Reminder: A vent with a larger inside diameter will reduce the risk of the vent freezing during periods of extreme cold temperatures.

Best Management Practice – Venting Wells

Any well, even a well in a well pit, should be vented to disperse gases. A well in a well pit should be vented with a shielded and screened vent (see Figure 9-29 in this chapter).

Reminder: The largest possible vent area (cross-sectional area) should be selected to help prevent freezing during periods of extreme cold.

Figure 9-15: Watertight Cap With Extendable Screened Air Vent Located Above The Well Cap

Figure 9-16: Watertight Cap With Snorkel Vent Used To Prevent Flood Water From Entering The Top Of A Drilled Well

Figure 9-17: PVC Well Seal Air Vent

This shows an example of a ½ inch air vent that can be threaded on a sanitary well seal as the one shown in Figure 9-14.

Figure 9-18: Vented Vermin Proof Cap Attached To Well Casing

Figure 9-19: Vent Locations On The Underneath Portion Of Three Vermin Proof Caps Commonly Used In Ontario

Wells Encountering Gas

The *Wells Regulation* - Where a well is constructed and natural gas is encountered, the person constructing the well must immediately notify the well purchaser, the owner of the land on which the well is situated and the Director that the condition exists.

The *Wells Regulation* - If a well is producing a natural gas or other gas and the gas is detected, the well owner must do at least one of the following:

- Abandon the well and take the necessary steps to plug and seal the well,
- Take the necessary measures to manage the gas in a way that prevents any potential hazards and ensure the measures are functional at all times, or
- Seek the written consent from the Director to allow for the continued use of the well (see Chapter 14: Abandonment: When to Plug & Seal Wells).

Reminder: See the Encountering Gas, Contamination and Water Quality Problems section of Chapter 5: Constructing the Hole, Casing & Covering the Well for further information and best management practices dealing with natural gas.

Best Management Practice – Venting Natural Gas

If natural gas or other gas has been identified, then the person constructing the well should consider retaining the services of a Professional Engineer or Professional Geoscientist experienced in groundwater and water wells producing gas. The Professional Engineer or Professional Geoscientist should:

- assess the well and the hydrogeology and geology around the well,
- provide the well owner with written recommendations, and
- confirm that the recommendations have been implemented and the gas concerns have been abated at the site.

Best Management Practice – Notification for Gases Other than Natural Gas

When "other" gases (e.g., benzene gas from a petroleum hydrocarbon spill) that cause, or may cause, adverse effects on public health and/or the natural environment are encountered, then the person constructing the well should notify the Spills Action Centre at . The Spills Action Centre alerts the various Ministry organizations including the local district office of the Ministry. In addition, the local fire department should be contacted.

Wells Caps And Covers

The purpose of well caps and covers is to prevent the entry of surface water and other foreign material into the well. The following requirements will apply to covering the well unless an exempted activity is being performed.

The *Wells Regulation* - If the well is constructed by a method other than boring and digging (i.e., jetting, drilling, and driving) the person constructing the well must seal the top of the casing with a commercially manufactured vermin-proof well cap.

For example, wells constructed by drilling, jetting and driving are captured by this well cap requirement.

The *Wells Regulation* - If a well is constructed by boring and digging, the person constructing the well must cover the top of the casing with a solid, watertight well cover that prevents the entry of surface water and other foreign materials.

Preventing the entry of other materials includes designing the well cover to be of sufficient strength to withstand any known weight that might be applied to the well cover or cap and the freezing and thawing action that may cause the cover to break.

Reminder: It is important that anyone constructing a well install the well cover or cap to the design specifications provided by the manufacturer and ensure that the design will work for the environment and well.

Covering The Well

Dug Or Bored

The person constructing the well must cover the top of the well casing with a solid watertight well cover so that surface water and other foreign materials can not enter into the well. This includes fastening and securing the cover to reduce the risk of children being able to access the well.

Figure 9-20: Dug Well With A Solid Well Cover

Figure 9-21: Dug Well Cover With Watertight Plastic Access Lid Added To Well Cover

Figure 9-21 shows the green coloured access lid is sealed to the top of the concrete cover using a butyl joint non toxic sealing material (mastic sealing material). An opening (not shown) exists in the centre of the concrete. The top of the access lid is affixed to the access lid riser using screws. The access lid and remaining well cover must prevent the entry of surface water and foreign materials from entering the well.

Reminder: Figure 9-22 to Figure 9-25 are for illustrative purposes only and do not necessarily represent full compliance with other requirements found in the *Wells Regulation*.

Figure 9-22: Well Cover Access With Plastic Lid

The figure is a cross-sectional view of a large diameter concrete well with a plastic access lid.

There are four components to the well; there are two concrete tiles that make up the casing, on top of which lies a concrete well cover, which has a plastic access lid.

The lower concrete tile is shown completely below ground surface. The upper concrete tile is on top of the lower tile, and it is noted that the joint between the tiles is sealed. About one-third of the upper concrete tile is above ground surface. The ground surface is highest around the well, with ground surface sloping away from the well.

The concrete well cover has a large diameter opening in the centre of the cover to facilitate access into the well casing. The plastic access lid is installed in the middle of the concrete well cover and seals the opening of the concrete well cover.

On the left side of the figure, there are two exploded views. The first exploded view is of the seal between the concrete well cover and plastic access lid, which illustrates a mastic sealant between the cover and lid. The second exploded view is of the plastic access lid, and illustrates the use of a pin or screw in the lid to prevent the top of the lid from opening.

Solid cover including access lid must be properly designed to prevent physical hazards and must be sufficiently attached to the casing to prevent surface water and other materials from entering the well.

A common type of mastic sealant material is non-toxic butyl sealant.

Figure is not to scale; all dimensions and locations are approximate. This figure does not reflect a situation where an air vent would be necessary to safely vent gas from the well site.

Figure 9-23: Well Cover Access With Concrete Lid

The figure is a cross-sectional view of a large diameter concrete well with a concrete access lid.

There are four components to the well; there are two concrete tiles that make up the concrete casing, on top of which lies a concrete well cover, which has a concrete access lid.

The lower concrete tile is shown completely below ground surface. The upper concrete tile is on top of the lower tile, and it is noted that the joint between the tiles is sealed. About one-third of the upper concrete tile is above ground surface. The ground surface is highest around the well, with ground surface sloping away from the well.

The concrete well cover has a small diameter opening in the centre of the cover to facilitate access into the well casing. The concrete access lid is installed on top of the concrete well cover and seals the opening of the concrete well cover. A weather-proof flexible neoprene (rubber or mastic sealant) is shown below the concrete access lid which is used to seal between the lid and cover. The access lid has a semi-circle shaped handle to lift the lid off of the cover.

Solid cover including access lid must be properly designed to prevent physical hazards and must be sufficiently attached to the casing to prevent surface water and otehr amterials from entering the well.

A common type of mastic material is non-toxic butyl sealant.

Figure is not to scale; all dimensions and locations are approximate. This figure does not reflect a situation where an air vent would be necessary to safely vent gas from the well site.

Figure 9-24: Well Cover With No Access Lid

The figure is a cross-sectional view of a large diameter concrete well with a concrete well cover.

There are three components to the well; there are two concrete tiles that make up the concrete casing, on top of which lies a concrete well cover.

The lower concrete tile is shown completely below ground surface. The upper concrete tile is on top of the lower tile, and it is noted that the joint between the tiles is sealed. About one-third of the upper concrete tile is above ground surface. The ground surface is highest around the well, with ground surface sloping away from the well.

The concrete well cover does not have an opening and provides cover for the entire well casing. Two metal handles are shown as anchored into the concrete cover.

Solid cover including access lid must be properly designed to prevent physical hazzards and must be sufficiently attached to the casing to prevent surface water and other materials from entering the well.

A common type of mastic sealant is non-toxic butyl sealant.

Figure is not to scale; all dimensions and locations are approximate. This figure does not reflect a situation where an air vent would e neccessary to safely vent gas from the well site.

Reminder: The joint between the concrete well cover and the top casing shown in both Figure 9-23 and Figure 9-24 must be sealed with a mastic sealing material strip (i.e., butyl joint non toxic sealant) in areas where flooding is anticipated to occur.

Figure 9-25: Well Cover With Metal Sleeve

The figure is a cross-sectional view of a large diameter concrete well with a metal sleeve overtop of a concrete access lid.

There are five components to the well; there are two concrete tiles that make up the concrete casing, on top of which lies a concrete well cover, which has a concrete access lid. The lid and cover are enveloped by a metal sleeve.

The lower concrete tile is shown completely below ground surface. The upper concrete tile is on top of the lower tile, and it is noted that the joint between the tiles is sealed. About one-third of the upper concrete tile is above ground surface. The ground surface is highest around the well, with ground surface sloping away from the well.

The concrete well cover has a small diameter opening in the centre of the cover to facilitate access into the well casing. The concrete access lid is wedge-fit into the concrete well cover and seals the opening of the concrete well cover. The access lid has a semi-circle shaped handle to lift the lid off of the cover.

A metal sleeve is attached to the outside of the concrete well cover and provides a shield to the cover and lid.

Cover, including access lid and metal sleeve, must be properly designed to prevent physical hazards and must be sufficiently attached to the casing to prevent surface water and other material from entering the well.

Figure is not to scale; all dimensions and locations are approximate. This figure does not reflect a situation where an air vent would be necessart to safely vent gas from the well site.

Reminder: The joint between the concrete well cover and the top casing shown in Figure 9-25 must be sealed with a mastic sealing material strip (i.e., butyl joint non toxic sealant) in areas where flooding is anticipated to occur.

Drilled Or Other

The person constructing the well must seal the top of a well casing, that is not constructed by digging or boring, a commercially manufactured vermin-proof well cap. This includes a properly installed and sealed sanitary well seal, and a watertight and airtight well cap for a jetted or driven point well.

Reminder: Waterlines sealed to the top of the casing and to a pump under a vacuum are considered vermin-proof well caps for dewatering systems using shallow point wells.

Figure 9-26: Vermin Proof Well Cap

Figure 9-27: Vermin-Proof Cap And Threaded Conduit

Alternative To A Well Cap Or Cover

The *Wells Regulation* - The cover, cap or seal is not required if all of the following criteria are met:

- a floor has been constructed around or adjacent to the casing of the well,

- a pump (includes associated equipment such as waterlines) is installed above or adjacent to the well. (This scenario would include wells with a vertical turbine pump, hand pump or other type of pump positioned directly over the casing),
- the top of the casing is shielded in a manner sufficient to prevent entry of any material that may impair the quality of the water in the well, and
- the casing of the well is extended to at least 15 cm (6 inches) above the floor that has been constructed around or adjacent to the casing of the well.

Figure 9-28: Example Of A Well Not Requiring A Cover, Cap Or Seal - Vertical Turbine Pump Installed Directly Over The Well Casing

Casing Height And Mounding

The *Wells Regulation* - Unless exempt, any person installing equipment in a well must ensure that the casing height, mounding and surface drainage meet requirements discussed in Chapter 7: Completing the Well's Structure.

Well Pits

In most circumstances, well pits are not allowed to be constructed on new or existing wells.

The *Wells Regulation* - In only two circumstances, however, a person constructing a new well may be allowed to finish the well with a well pit. The *Wells Regulation* provides options for the construction of permitted well pits depending on the location of the well, the type of equipment used to construct the well and the well's purpose. The two permitted circumstances are:

1. The *Wells Regulation* permits the construction of a new well with a well pit as long as the well is constructed with diamond drilling equipment in connection with mineral exploration.
2. The *Wells Regulation* permits the construction of a test hole or dewatering well with a new well pit or the addition of a new well pit to an existing test hole or dewatering well if the well is located where vehicle or pedestrian traffic is likely to pass directly over the well and the well is completed with a flush-mounted well cover in accordance with the *Wells Regulation*.

Along with the information provided in this section, see the "Plainly Stated" section in this chapter for further requirements and information on permitted well pits.

Well pits are usually installed at or near the time of pump and associated equipment installation in the well. The top of the well casing extends out of the floor of the well pit.

A well pit is designed to:

- contain the upper portion of a drilled well,
- prevent the upper portion of the well, and
- waterlines from freezing and allow access to the top of the well.

Well pits were the preferred choice of pump installers when installing waterlines out of the top of a drilled well to a building until the widespread use of submersible pumps, pitless adapters and pitless units began.

There are many problems associated with well pits in Ontario, such as:

- surface water can pond around the casing and above the top of drilled wells,
- large openings in the well pit's walls can allow surface water and foreign materials to enter the pit and possibly, the top of the well, impairing the well water,
- the structure can be unsafe,
- the structure can be subject to frost heave,
- flush-mounted well pits (vaults) may be damaged by snow removal or other vehicles, and
- surface water can enter the well and cause groundwater mounding.

Reminder: A well pit is considered a confined space. There are many serious risks and hazards associated with this type of confined space including electrocution, asphyxiation, physical hazards such as drowning or falling, presence of poisonous gases and explosive gases. All required preventative measures when entering a confined space must be undertaken prior to accessing or entering any well pit. Further requirements are found in *Ontario Regulation 632/05 (Confined Spaces)* made under the *Occupational Health and Safety Act*.

Well Pit Walls (Or Casing)

The following *Wells Regulation* requirements apply when a new permitted well pit is constructed for a new well.

The person constructing the well must:

- consider the walls of the well pit as "casing" and
- meet the casing requirements found in Chapter 5: Constructing the Hole, Casing & Covering the Well and Chapter 7: Completing the Well's Structure in this manual.

For example, if a permitted well pit is installed for a well, the person constructing the well must ensure that the well pit casing is:

- made of new material, unless it is scheduled to be abandoned within 180 days of completion of the structural stage,
- clean and free of contamination, and
- watertight, including any seams.

As another example, if concrete material is used as well pit casing, the person constructing the well must ensure that the:

- casing sections are properly aligned so that the joints are flush and the casing is centred,
- casing is commercially manufactured and fully cured, and
- joints between casing sections are sealed with a mastic sealing material (e.g., butyl rubber material) approved by the NSF International that remains pliable and waterproof.

Surface Drainage For A Well Pit

The following *Wells Regulation* requirement applies when a new permitted well pit for a new well.

The person constructing the well must ensure that surface water drainage is such that water will not collect or pond in the vicinity of, or within, a permitted well pit's casing.

Creating And Filling The Well Pit's Annular Space

The following *Wells Regulation* requirements apply when a new permitted well pit is constructed for a new well.

The person constructing the well must:

- ensure that the entire new well pit, from the bottom of the well pit to the ground surface, is constructed with a diameter that is at least 7.6 cm (3 inches) greater than the outside diameter of the well pit's walls (or casing).
- fill any annular space outside the permitted well pit's casing, from the bottom of the well pit to the ground surface, with suitable sealant.
- use a suitable sealant with the appropriate structural strength to support the weight of persons and vehicles that may move over the area after it is filled.

If the suitable sealant contains cement, the person constructing the well must:

- allow the cement to set according to the manufacturer's specifications or for 12 hours, whichever is longer; and
- if, after setting, the sealant has settled or subsided, top up the cement to the ground surface.

Best Management Practice – Protection from Frost Heave for Flush-Mounted Well Pits (Vaults)

To reduce frost heave, concrete should be used as a suitable sealant in the annular space and below the flush-mounted well pit (vault). The concrete should extend at least 10 cm (4 inches) from the outside of the vault and at least 30 cm (12 inches) below the frost line

Well Pit Floor

The following *Wells Regulation* requirement applies when a new permitted well pit is constructed for a new well.

The person constructing the well must cover the floor of the new well pit with at least a 10 cm (4 inches) thick layer of suitable sealant that when set to a solid state will be capable of supporting the weight of a person.

Best Management Practice – Well Pit Floor

It is important that the suitable sealant used to construct the well pit floor be able to withstand the pumping of any water from the floor of the well pit. Some sealants, such as bentonite, may erode during pumping of water from the well pit's sump, whereas properly cured concrete will not likely be removed during the pumping of water with a sump pump in any well pit sump hole.

Well Pit Cover

The following *Wells Regulation* requirements apply when a new permitted well pit is constructed for a new well.

The person constructing the well must cover of the well pit with a solid, watertight cover, sufficient to prevent the entry of surface water and other foreign materials into the well pit.

The following *Wells Regulation* requirement applies when a new permitted well pit is constructed for a new well that has been constructed with diamond drilling equipment in connection with mineral exploration.

The person constructing the well must fasten and secure the cover of the well pit in a manner that will make it difficult for children to remove it.

Keeping The Well Pit Dry

The following *Wells Regulation* requirements apply when a new permitted well pit is constructed for a new well that has been constructed with diamond drilling equipment in connection with mineral exploration.

Sump Pump

The person constructing the well must ensure that the new well pit is kept dry by means of a sump pump. This could also mean a sump hole would need to be installed into the floor of the well pit.

Drainage Pipe

If the water table is substantially lower than the floor of a permitted well pit, the person constructing the well may ensure that the new well pit is kept dry by means of a drainage pipe that:

- has a one-way valve to allow water to discharge from the pit but prevents surface water and other foreign materials, including insects and animals, from entering the well pit,
- passes through the layer of sealant, and
- allows water to discharge near the perimeter of the well pit.

As indicated in the best management practice titled "Well Pit Floor" in this section, the suitable sealant used to construct the well pit sump hole should be able to withstand the pumping of any water from the well pit.

Well Casing Height Above Well Pit Floor

The following *Wells Regulation* requirement applies when a permitted well pit is constructed with or added to a new well that has been constructed with diamond drilling equipment in connection with mineral exploration.

The person constructing the well must extend the top of the well casing at least 40 cm (16 inches) above the floor of the new well pit.

Well Cover/Seal & Vent In A Well Pit

The following *Wells Regulation* requirements apply when a new permitted well pit is constructed for a new well that has been constructed with diamond drilling equipment in connection with mineral exploration.

The person constructing the well must:

- seal the top of the drilled well casing inside the new well pit with a commercially manufactured sanitary well seal and
- provide an air vent line from the commercially manufactured sanitary well seal to above the cover of the new well pit.

Reminder: The top of a well inside a new well pit, including a new flush-mounted well pit (vault), must be sealed with a commercially manufactured vermin-proof cap or solid watertight well cover. A commercially manufactured sanitary well seal is considered to be a commercially manufactured vermin-proof cap. For further information on covering a well, see the “Covering the Well” section in this chapter.

Reminder: To meet the above venting requirement in a permitted well pit, the air vent may extend through the side of the well pit casing (see Figure 9-29 in this chapter).

Best Management Practice – Shield and Screen Air Vent Line on Well Pit

It is important that the well’s air vent in a well pit be shielded and screened in a way that prevents the entry of surface water and other foreign materials

The venting requirements for a drilled well completed with a well pit, and where a pump is installed in the well, are detailed in the “Venting During Pump Installation in Drilled Wells” section in this chapter.

Figure 9-29: An Example Of A Well Pit With Sump Pump And Gravity Drain Drainage

The figure is a cross-sectional view of a well inside of a concrete well pit. There are two major components to the figure; the well and its components, and the well pit and related components.

The drilled well is located at the bottom right of the well pit and below the frost line. As a minimum, the top forty centimetre portion of the well casing is exposed within the well pit, while the rest of the casing is below the bottom of the well pit. The annular space of the drilled well below the well pit is sealed with a suitable sealant.

The top of the drilled well has a sanitary seal from which two pipes extend vertically; a water pipe and an air vent. Both water pipe and air vent bend ninety degrees to the right, slightly above the well casing, and exit the well pit below the frost line. The water pipe and air vent exit the pit through a watertight connection to the well pit casing with durable bonding material. The water pipe is illustrated as remaining horizontal and extending to a distribution system. The air vent has another ninety degree bend and extends vertically through the well pit casing sealant to above ground surface. The top of the air is screened and shielded.

The well pit consists of two concrete tiles with a concrete base with a minimum thickness of ten centimetres (four inches) and a solid, watertight and child proof well pit cover. The lower concrete tile is shown completely below ground surface. The upper concrete tile is on top of the lower tile, and it is noted that the joint between the tiles is sealed with mastic sealant strip (e.g., butyl joint non-toxic sealant). About one-third of the upper concrete tile is above ground surface. The ground surface is highest around the well, with ground surface sloping away from the well. It is noted that mounding around the well is to prevent pooling of water around the well. It is further noted that the casing height above ground surface must be at least forty centimetres (sixteen inches). The well pit is constructed in an excavation which is filled with a suitable sealant and is able to withstand the weight of persons, animals, and vehicles.

On the bottom left side of the well pit, there is a water draining device (sump pump) shown. There are two options for drainage, which are detailed in Exploded Views A and B.

Exploded View A illustrates a sump pump at the bottom of the well pit. The sump pump has a discharge line that extends vertically to above ground surface, where the line bends to the left and exits the concrete tile through a watertight connection to the well pit casing. The discharge line is slightly raised above ground surface to provide a sufficient air gap, and has a one-way valve at the end to prevent insects from entering the pit.

Exploded View B illustrates a gravity drain at the bottom of the well pit. The drain has a one way valve inside the well pit. The drain exits the well pit through a watertight connection, with the drain pointing to a point at a lower elevation than the floor of the well pit. There is a note that states “B is an alternative to A when the water table is substantially lower than the floor of the well pit.”

Sometimes the pump and air tank are located within the well pit.

Reminder: Larger diameter well pits must not be entered as they are a safety hazard. Well pits must only be entered when adequate safety precautions are followed based on the *Confined Spaces Regulation, Ontario Regulation 632/05* as amended under the *Occupational Health and Safety Act*.

Reminder: This figure is not to scale, is for illustrative purposes for this chapter only and does not necessarily represent full compliance with other requirements found in the *Wells Regulation*

Tools

Tables 9-4 and 9-5 provide information on drop pipes (waterlines) and other equipment installed in a well.

The *Wells Regulation* - Any equipment installed in the well must be clean.

Table 9-4: Drop Pipe Comparison

Pipe Type & Description	**Diameter Range**	**Length Availability**	**Pressure Rating**	**Application**
Galvanized Steel Pipe & Black Steel Pipe Black Pipe [steel pipe in which the outer diameter has been lacquered (as opposed to bare or galvanized pipe)].	2.5 cm (1 inch) to 20 cm (8 inches)	6.4 m (21ft), and 3 m (10ft) lengths threaded together	438 – 13,110 kPa (700 – 1,900 psi)	• Superior strength • Associated with deep wells • Is heavy and requires pump truck • Can react adversely with certain water chemistry. (e.g. low pH)
PVC Pipe – Medium and High Density	3.2 mm (1⁄8 inch) to 61 cm (24 inches)	30 m (100ft), 60 m (200ft), and 457 m (1,500ft) lengths	28 - 8,487 kPa (120 – 1,230 psi)	• Can be handled without pump truck or similar equipment • Is not reactive to most water chemistry • Medium density PVC pipe is more easily handled in cold weather than high density PVC pipe
Polyethylene Pipe	1.9 cm (¾ inch) – 20 cm (8 inches)	Straight pipe: 12 m (40ft), 15 m (50ft), 18 m (60ft), 30 m (100ft), 90 m (300ft), 300 m (1,000ft), and 450 m (1,500ft) lengths, On Reel: up to 3,000 m (9850ft) lengths	Up to 20,010 kPa (2,900 psi)	• Is not reactive to most water chemistry • Can be glued, threaded or heat fused • Tough but flexible • Softer than metal and may be damaged by abrasion

Reminder: These drop pipes are all approved by NSF International for potable water.

Table 9-5: Typical Equipment Installed In Wells

Component	**Description**	**Graphic**
Single Pitless Adapter	• 2.5 cm (1 inch) Single pitless adapters are the most widely used connection for domestic submersible pumps in drilled wells • 3.2 cm (1 ¼ inch) used for shallow well jet pumps • Available in brass and stainless steel	
Weld On Pitless Adapter	• Strong and durable • Typically used for larger diameter wells and municipal wells • Available in steel only	

Component	Description	Graphic
Clearway Pitless Adapter	• Enables work on the well such as deepening or rehabilitating (i.e. bio-foul on a municipal well – enables a well contractor to put full gauged tools down the casing) • Also allows for a 10 cm (3 ⅝ inch) pump in a 10 cm (4 inches) casing. Customer does not need to purchase a special pump (money savings) • Available in brass and stainless steel	
Clamp On Pitless Adapter	• The durable cast steel pitless adapter housing is clamped on the outside of the casing • The water contacts only stainless steel and brass, which eliminates corrosion • When the brass tee insert is pulled, there is no obstruction left in the well and the inside diameter of the casing is completely open - can be used with steel and PVC casing as small as 10 cm (4 inches) in size	
Double Pipe Pitless Adapter	• Similar to a single pipe, but provides a two-pipe connection for the waterlines of a jet pump • Available in brass and stainless steel	
Cement/Concrete Tile Pitless Adapter	• Used on cement/concrete tile • Has an extended shank to allow the pitless slide to be installed through a cement casing • Available in brass	
Corrugated Pitless Adapter	• Used for galvanized or fiberglass casings • Available in brass only	
Wire	• Used for running submersible pumps in wells • Stranded wire – woven • Lay flat – side by side	
Link Seal	• Used to seal an electrical conduit or horizontal pipe that extends through a well casing. Typically used where an electrical conduit passes through the well casing of a large diameter dug or bored well • Forms a hydrostatic seal up to 275.8 kPa (40 psi)and up to 12.2 m (40ft) of head pressure • Electrically isolates the inner carrier pipe from the penetrated structure	
Flow Control	• Available in various US gallon per minute ratings • Can be installed on pump discharges to prevent over pumping of the well • Make sure pressure on a pump side of the Dole Flow Valve should not exceed 827.4 kPa (120 psi)	
Foot Valves	• Function is to keep jet pumps or piston pumps primed • Can be stainless steel, brass or plastic	
Check Valves	• A check valve is used to prevent water from the system from running back into the well when the pump isn't running • Used with submersible pump to minimize pressure surges on the drop pipe (e.g. For a well that is 91 m (300ft) deep, one check valve is placed at the pump, another at the pressure tank and a final valve is placed at 45.5 m (150ft) below the ground surface in the drop pipe)	
Air Tight Cap	• A smaller cap is required for driven point wells and jetted wells due to their small diameter • Typically threaded onto the top of the casing	

Component	Description	Graphic
Solid, Watertight Well Cover	• Prevents the entry of foreign material into the well • Typically used for dug or bored wells • There are other types of solid, watertight well covers not shown in this table (see "Well Caps and Covers" section in this chapter)	
Suspension Bracket (rope hanger)	• Used to attach a safety cable to the pump • Fits on top of a drilled well casing and is easily covered by a vermin- proof well cap	
Lightening Arrestor	• Usually built into the pump • Separate component for pumps used in high capacity wells (e.g, municipal wells)	
Deep Well Ejector	• Part of deep well jet pump assembly • Used in conjunction with deep well jet pump	Two Pipe Deep Well Ejector Single Pipe Deep Well Ejector
Cable Guards/Cable Ties	• To protect the wire, use cable guards and cable ties	
Torque Arrestors	• Usually located directly above the pump • Function is to prevent pump damage by stopping the pump from turning in the well, moving in the well, or banging into the side of well	
Flow Inducer Sleeve	• A physical sleeve attached to a submersible pump assembly designed to channel water over the pump motor before it enters the pump intake • This provides the pump motor with a consistent supply of fresh water for cooling	
Clamps	• Used to join poly pipe to insert fittings • Make sure they are all stainless steel with stainless steel screws	
Splice Kit	• For attaching electrical wire to a submersible pump and connecting wires at wellhead • Must be waterproof and CSA approved	
Insert Adapter	• Threaded at one end • Barb fitting opposite end • Joins pipe to pipe thread	
Gas Trap	• A physical sleeve attached to the submersible pump to channel water into the waterline and attempts to prevent gas from entering the waterline • However, the trap will not remove compounds such as methane that have not come out of solutions	

The *Wells Regulation* - Any equipment installed in the well must be clean.

Reminder: Always follow Manufacturer's recommendations and guidelines with any piece of equipment.

10. Yield Test

Chapter Description

This chapter discusses the reasons, procedures and methods of measuring water levels in the well and testing the well yield. The requirements under the *Wells Regulation* are introduced and discussed. It also summarizes what should be done with the discharge water from the testing process, keeping in mind potential contamination and other environmental concerns. This chapter does not cover pumping tests designed to determine aquifer performance and characteristics.

Regulatory Requirements - Yield Test

Relevant Sections - The *Wells Regulation*

- Well Yield – Sections 14.9 to 14.10
- Installation of Equipment – Section 15.3

The Requirements - Plainly Stated

Unless exempt, the *Wells Regulation* requires the following when testing the yield of the well:

When to Perform a Test of the Yield of the Well

The person constructing the well must test the yield of a well before the well's structural stage is complete.

Exemptions – Testing Yield of Well

Testing the yield of the well is not required in any of the following situations:

- the well or activity is exempt from the *Wells Regulation*,
- a minor alteration,
- an installation of a pump, or
- an alteration that only involves:
  - the removal of the casing above the ground surface so that the casing is flush with the ground surface (test holes and dewatering wells only, see "Casing Height When Performing Work On or Near a Well" section of Chapter 11: Maintenance & Repair),
  - the addition of casing above the ground surface, or
  - the addition or removal of a well pit.

Reminder: For further information on the term "minor operation" see Chapter 2: Definitions & Clarifications, Table 2-1.

Equipment

A person who installs equipment in a well must ensure that the equipment is clean.

Reminder: For further information on the term "clean" see Chapter 2: Definitions & Clarifications, Table 2-2.

When to Measure and Record Water Levels

When testing the well yield, the water level in the well must be measured and recorded as follows:

- immediately before commencement of pumping,
- at 1 minute intervals or more frequently during the first five minutes of pumping,
- at 5 minute intervals or more frequently during the next 25 minutes of pumping,
- at 10 minute intervals or more frequently during the next 30 minutes of pumping,
- at 1 minute intervals or more frequently during the first five minutes after pumping stops,
- at 5 minute intervals or more frequently during the next 25 minutes after pumping stops, and

- at 10 minute intervals or more frequently during the next 30 minutes after pumping stops.

Devices to Use to Record Water Levels

When measuring the water level, the person constructing the well must use a clean plastic or metal tape or an air line or clean electrical device

Exemption – Measuring Water Levels

The above water level measurement requirements do not apply if the design of the well does not allow for the water level in the well to be measured during the yield test.

The water in the well, however, must still be pumped as stated in the "Measuring and Recording the Pumping Rate section of the Plainly Stated.

Measuring and Recording the Pumping Rate

The person constructing the well must

- pump the water from the well, at a steady rate, continuously for at least one hour, and
- record the rate of pumping during the test on the well record.

If water cannot be pumped from the well continuously for one hour, no further measurements are required and the person constructing the well must record the following on the well record:

- the reason pumping was discontinued,
- the rate of pumping and the length of the pumping period, and
- the water level measurements made.

Relevant Guidelines

Procedure D-5-5 titled Technical Guideline for Private Wells: Water Supply Assessment, by Ministry of the Environment, Last Revision, August 1996.

Relevant Sections - Additional Regulations Or Legislation

Ontario Water Resources Act section 30 – Discharge of Polluting Material Prohibited (Impairment of Quality of Any Waters)
Ontario Water Resources Act section 34 – Taking of Water (Permit to Take Water)
Ontario Water Resources Act section 53 – Sewage Works (Environmental Compliance Approval)

Key Concepts

Importance Of The Yield Test

The well yield test provides important information about:

- performance of the well, and
- some initial characteristics of the aquifer at the time that the well is tested.

The yield test information is used for a variety of purposes including, but not limited to:

- determining the sustainable rate at which the well will produce water
- selecting the appropriate pump size and type
- determining if conditions have changed that may indicate problems

Reminder: The yield test, as required by the *Wells Regulation*, is not for testing aquifer characteristics. For further information on aquifer characteristic testing please see: Technical Guidance Document For Hydrogeological Studies In Support of Category 3 Applications for Permit to Take Water published by the Ministry of the Environment, Operations Division, April 2008.

Reminder: There is no minimum sustained rate for a residential water supply specified in the *Wells Regulation*. The yield test is a tool to inform the well owner of an estimate of the sustained rate at which the well can be pumped. For further information on residential and livestock water needs see: "Best Management Practices – Water Wells [1] " in this chapter.

Pumping Rate And Measurements

The *Wells Regulation* - The person constructing the well must meet the following measurement and pumping requirements when conducting a test of the yield of the well:

- immediately prior to pumping, the water level must be measured and recorded,
- the well must be pumped continuously, and at a steady rate throughout the test, and the pumping rate must be sustained for at least one hour,
- the pumping rates must be recorded on the well record,
- the pumping water levels must be measured and recorded:
  - at 1 minute intervals or more frequently for the first 5 minutes,
  - at 5 minute intervals or more frequently for the next 25 minutes, and
  - at 10 minute intervals or more frequently for the remaining 30 minutes of the test, and
- the recovery water levels must be measured and recorded at the same time intervals as outlined in the previous bullet.

Reminder: The recovery starts immediately after the pump has been shut off

Best Management Practice – Pumping Rate and Measurements

Installation of a dedicated and portable submersible pump and equipment used only for the purposes of conducting well yield tests (dedicated pump), will assist in conducting a steady rate (constant rate) yield test.

The pumping rate during the yield test should be similar to the intended pumping rate in order to replicate the well's probable water levels and usage.

The rate selected should take into consideration the volume of water that is in storage in the well to ensure that the test is conducted in a fashion that clearly identifies the sustainable yield of the well.

Pumping rates should be measured accurately and be recorded at least as often as water level measurements at 5 minutes of intervals.

ASTM D5737-95(2006) – "Standard Guide for Methods for Measuring Well Discharge [2] " should be followed to determine the best method to accurately measure the discharge of groundwater from the well.

Water levels should be measured with accurate meters such as an electrical device.

Conducting The Yield Test

The *Wells Regulation* - To be effective, a pumping test must be accurate. While there are several methods for determining approximate yield, such as the bailer method or the air lift method, only the pump method is an acceptable testing method according to the *Wells Regulation*.

Only a pump, such as a submersible, jet or shallow lift pump with appropriate control devices and valves, can be used to pump a well continuously, and at a steady rate, for at least one hour.

A bailer cannot be used to conduct the yield test as water is not being pumped at a continuous and steady rate.

Also, using a compressor and blowing air down drill rods cannot be used to conduct the yield test. This action disturbs the water levels in the well during the test and does not produce a continuous and steady rate of pumping. In addition, the bottoms of the drill rods are typically used as the measuring point for water levels. It is impossible to accurately measure the water levels during this disturbance. It is also impossible to accurately measure the water levels after pumping has stopped using this method because the water levels will rise above the bottom of the drill rods.

Permit To Take Water

A Permit to Take Water under the *Ontario Water Resources Act* is required for many types of water takings, including pumping a well for a yield test, that are greater than 50,000 L/day (11,000 G/day). Therefore, the person constructing the well should estimate the taking of water during the entire test before conducting the test. If the estimate shows the test will take more than 50,000 L/day, then the person constructing the well needs to obtain a Permit To Take Water from the Ministry prior to construction. Visit Permit to Take Water website for more information.

Considerations When Conducting A Yield Test

The person conducting the yield test will need to:

1. determine the yield test equipment needed to pump the well. For example:
   - determining the size and type of pump such as:
     - a submersible pump, and
     - a jet pump.
   - ensuring the appropriate discharge lines are clean and will not impair the quality of the water. The waterlines should meet potable water specifications (e.g., NSF International).
   - determing the type of flow metering and control devices such as:
     - a gate valve,
     - an orifice or rectangular weir,
     - a constant flow restrictor valve (dole valve),
     - a rotameter,
     - a calibrated bucket or barrel,
     - a high capacity flow meter, and
     - a manometer
   - determining the type of water level measuring devices such as:
     - an electrical device (e.g., water level meter, sonic meter, pressure transducer with datalogger),
     - an air line, and
     - a tape measure.
2. clean all of the equipment to be used in the well. The person should follow the sanitary practices found in “Sanitary Practices” section in Chapter 8: Well Disinfection, to ensure equipment is clean.
3. set the intake in the well at a depth to make best use of available drawdown.
4. select an appropriate location for the discharge. The person should follow the “Handling Water Discharge” in this chapter for further guidance.
5. prevent any backflow of water down through the riser and discharge pipes and into the well. This is important to minimize the risk of contamination and interference with recovery water level measurements.
6. measure and record the static water level.
7. Begin pumping at a steady rate and pump continuously for at least one hour. Pumping rates should be measured accurately and should be recorded at least as often as water level measurements after 5 minutes of pumping. See the “Best Management Practice – Pumping Rate and Measurements” in this chapter.
8. measure and record the pumping water level measurements. See the “Pumping Rate and Measurements” section and “Recording Yield Test Results” section in this chapter.
9. shut down the pump at the end of the pumping portion of the test. The exact time and water level when the pumping stops must be observed and recorded. This is time zero of the recovery portion of the test.
10. measure and record recovery water levels for at least the next hour. See “Pumping Rate and Measurements” section and “Recording Yield Test Results” section in this chapter.

Best Management Practice – Extending the Pumping Time Past Minimum Requirement

A longer pumping test provides more information to:

- determine the sustainable yield of the well, and
- provide greater confidence that the well can sustain the desired rate.

Handling Water Discharge

The discharge water from a yield test must not cause an adverse effect to the natural environment and should not affect the yield test. To reduce risks, the following should be considered:

- during the yield test, water should be discharged a sufficient distance away from the well being pumped to minimize or eliminate recharge of this water to the aquifer during the test,

- water discharged during the yield test should not be allowed to pond or collect near the well, and
- the location of the discharge take potential environmental impacts such as erosion, impairment of surface water bodies and off-site flooding into consideration (see Sewage Works Approvals section in this chapter).

Sewage Works And Other Discharge Approvals

A sewage works Certificate of Approval under the *Ontario Water Resources Act* may be required if the person discharges the water from the well owner's property and the discharge capacity exceeds 10,000 litres per day. It is important for the person to determine if an environmental compliance approval is required before discharging the well water during the testing of the well yield. A guide to explain the sewage works process can be found on Ontario.ca.

If the discharge of water will be into a sanitary or storm sewer during a yield test, the person may require an approval for the discharge of water to the sanitary and storm sewer collection system. In cases where water well be discharged into a sanitary or storm sewer, a person should contact the applicable upper and lower tier municipalities early in the planning process to determine if any specific approvals are required by the municipality along with the process to obtain the required approvals.

Recording Yield Test Results

Figure 10-1 shows the details that are required on the well record. Further details are shown in Chapter 9: Equipment Installation and Chapter 13: Well Records, Documentation, Reporting & Tagging.

Figure 10-1: Well Record - Test Of Well Yield

- After test of well yield, water was:
  - Clear and sand free
  - Other, specify
- If pumping discontinued, give reason
- Pump intake set at (m or ft)
- Pumping rate (l/min or GPM)
- Duration of pumping: hours + minutes
- Final water level end of pumping (m or ft)
- If flowing give rate (l/min or GPM)
- Recommended pump depth (m or ft)
- Recommended pump rate (l/min or GPM)
- Well production (l/min or GPM)
- Disinfested? Yes or No
- Draw Down
  - Time (minute)
  - Water level (m or ft)
- Recovery
  - Time (minute)
  - Water level (m or ft)
- Static level

Reasons For Discontinuing The Yield Test

The *Wells Regulation* - If water cannot be pumped from the well continuously for one hour, no further measurements are required and the following must be recorded on the well record:

- Reason pumping was discontinued
- Rate of pumping and the length of the pumping period
- Water level measurements made. This includes all recovery water level measurements made after pumping stops. Recovery water levels must be measured and recorded:
  - at 1 minute intervals, or more frequently, for the first 5 minutes after pumping stops,
  - at 5 minute intervals, or more frequently, for the next 25 minutes after pumping stops, and
  - at 10 minute intervals, or more frequently, for the remaining 30 minutes after pumping stops.

Some reasons for discontinuing the test include:

- the well running dry,
- encountering poor water quality, or

- the pumping of the groundwater is causing a quantity or quality interference problem with other wells.

Reminder: Equipment breakdown is not an acceptable reason for discontinuing the yield test as it is expected that the test will be re-done. Use well maintained equipment and fully charged generator sets.

Best Management Practice – Re-Doing Yield Test if the Well is Pumped Dry

If the initial yield test shows the well cannot be pumped for one hour, the person constructing the well should have obtained enough information to estimate well's actual sustainable yield. To provide the well purchaser with an understanding of the well's actual sustainable rate, the person constructing the well should re-do the yield test at the lower estimated rate using the minimum requirements of the *Wells Regulation* outlined in this chapter. The information gathered from the second test can be provided on the well record in place of the initial test.

Data Accuracy

The yield test data provides important information for the person installing the pump, the well purchaser and the well owner. It is important to fill out the well record with care and as accurately as possible. The yield of a well can change significantly over time. The well record data provide necessary background information to assist in the determination and resolution of potential problems with the well. This could include water quality, quantity or operational problems.

For example:

- The original well record showed a recommended pumping rate of 45 LPM (10 GPM) and the static water level of 5 m (16ft). A current pumping test shows that the well is yielding 5 LPM (1.1 GPM) and the static water level of 20 m (65ft). The decrease in the flow and the lower static water level suggests a problem associated with the aquifer as opposed to a problem with the pump equipment. This could be a result of nearby water taking or clogging of the well by biofilm or mineralization.

In many locations, the well records provide the only usable information on aquifer withdrawal rates. For example:

- Professional Geoscientists or Professional Engineers use the background information found on area well records to prepare for studies to evaluate area aquifers,
- in real estate transactions, the pumping test information is used to assist in determining if the well will meet the demands of the purchaser,
- a person constructing a new well can use area well records to estimate the rate of flow for a potential new well, and
- well records can assist a person constructing a well with determining the type of equipment to bring to the site.

Yield Test Terminology And Formulas

The following formulas illustrate how the data, collected during the yield test, can be used to determine drawdown and other characteristics to assist in determining equipment requirements as well as assist in troubleshooting.

Drawdown

The following formulas illustrate how the data, collected during the yield test, can be used to determine drawdown and other characteristics to assist in determining equipment requirements as well as assist in troubleshooting.

Drawdown = PWL – SWL

This difference represents the force that causes water to flow through an aquifer toward a well at the rate that water is being withdrawn from the well. The drawdown can be expected to increase as the pumping rate is increased.

Figure 10-2: Drawdown Diagram [3]

Residual Drawdown

After pumping is stopped, the water level rises and approaches the original static water level. During water level recovery, the distance between the recovery water level (RWL) and the initial static water level (SWL) is called residual drawdown.

Residual Drawdown = RWL – SWL

Specific Capacity

Specific capacity is the pumping rate divided by the drawdown (L/min/m or GPM/foot). The specific capacity is a measure of the drawdown caused by the pumping rate and is used as a basis for determining the well's performance. The specific capacity usually changes with both pumping rate and time.

Specific Capacity of a well = Pumping Rate ÷ Drawdown

Example:

- The pump is located 18 m (60ft) below ground surface and draws the water down to 15 m (50ft). The static water level is 9 m (30ft). The well is pumping at 45 L/min (10 GPM)

  Drawdown = 15 m – 9 m = 6 m (50ft – 30ft = 20ft)

  Specific Capacity = 45L/min/6 m = 7.5 L/min/m (10 GPM/20ft = 0.5 GPM/ft)

11. Maintenance & Repair

Chapter Description

This chapter provides the *Wells Regulation*'s maintenance requirements and recommended measures to prevent the entry of surface water and other foreign materials from entering a well and a well owner's responsibility to meet these requirements. The chapter also provides the requirements for well owners and persons who work at the construction (or alteration) of existing wells.

To assist well owners in meeting their obligations, the chapter presents preventative maintenance programs. Common well water quality and quantity problems and well structure issues with possible rehabilitation solutions are presented for both well owners and persons who work at the construction of wells. The chapter also provides suggestions on who should assess and rectify well problems, recognizing each well and its environment are unique, and the complications involved in well rehabilitation techniques.

Regulatory Requirements - Maintenance

Relevant Sections - The *Wells Regulation*

- Maintenance – Section 20
- Abandonment – Section 21, sub-sections 21(3), 21(4), 21(5), 21(6), 21(7) and 21(9)
- Protection of Well Tag – Sections 14.11 and 22

The Requirements - Plainly Stated

The *Wells Regulation* requires the following:

Well Maintenance

The well owner must maintain the well at all times after the completion of the well's structural stage in a way that prevents surface water and other foreign materials from entering the well.

Maintaining Casing Height Above the Ground Surface

For a well having a casing height that extends not less than 40 cm (16 inches) above the ground surface, a person must not reduce the height to less than 40 cm (16 inches) above the ground surface.

For an existing well having the top of the casing extending above the ground surface by less than 40 cm (16 inches), a person must not reduce the original casing height.

Exemption - Maintaining Casing Height for Driven Point or Jetted Point New Wells

An exemption to the minimum casing height requirement above the ground surface exists if the well is made by the use of a jetted point or driven point and it has a visible, permanent marker.

To qualify for this exemption:

- the casing must extend a sufficient height to permit the attachment of a well tag,
- the casing must be at least as high as the highest point on the ground surface within a 3 m (10ft) radius of the well's casing after the ground surface is properly mounded with earth to direct surface drainage away from the well as measured on completion of the well's structural stage, and
- the permanent marker must identify the location of the well and be visible at all times of the year.

Well Abandonment

The well owner must immediately abandon the well if the well is not being used or maintained for future use as a well.

The well owner must immediately abandon the well if the required measures or steps are not taken to address the following issues:

- the well produces mineralized water,
- the well produces water that is not potable,
- the well contains natural gas or other gas, or
- the well permits any movement of natural gas, contaminants or other materials between subsurface formations or between any subsurface formation and the ground surface, and the movement may impair the quality of any waters.

The well owner must immediately abandon the well if the well is constructed in contravention of the *Wells Regulation* requirements and the steps taken by the well owner to rectify the situation fail.

The person abandoning a well may seek the Director's written exemption from the requirement to abandon the well in some circumstances.

Reminder: For further information see Chapter 14: Abandonment: When to Plug & Seal Wells.

Well Tags

A person must not remove a well tag from a well unless:

- the well is being altered,
- the well is being abandoned, or
- the Director has given written consent for well tag removal.

If a well tag is removed during an alteration, the well tag must be safeguarded and re-affixed after the alteration has been completed.

No person shall deface, alter, conceal or obstruct an affixed well tag.

Any damaged well tags must be returned to the Ministry and be replaced.

Reminder: See Chapter 13: Well Records, Documentation, Reporting & Tagging for further information.

Reminder: See the "Well Repair Requirements for Persons Constructing Wells" section of this chapter for information on the requirements that apply for an "alteration" (including a repair) to a well.

Reminder: The requirements listed in this chapter do not apply to the exempted activities discussed in Chapter 3: Well Contractors & Well Technicians – Licences, Responsibilities & Exemptions. However, any construction activity on a well must not cause or have the potential to cause impairment to the water in the well or the groundwater as required under Subsection 30(1) of the *Ontario Water Resources Act*.

Relevant Sections - Additional Regulations Or Lesgislation

Electricity Act, 1998. S.O. 1998. Chapter 15, Schedule A; *Ontario Regulations 164/99: Electrical Safety Code*
Occupational Health and Safety Act, R.S.O. 1990, Chapter 0.1; *Ontario Regulation 632/05: Confined Spaces*
Safe Water Drinking Act, 2002. S.O. 2002, Chapter 32; *Ontario Regulation 169/03: Ontario Drinking Water Quality Standards*.

Relevant Guidance Documents

Fleming College. 2008. Manual for Continuing Education Course: Safety (for Ontario Well Technicians).

Key Concepts

Wells, like any equipment or structure, have a limited lifespan. They need preventative maintenance to keep supplying enough safe and reliable water for their users.

The *Wells Regulation* requires that the well owner must maintain the well at all times after the completion of the well's structural stage (i.e., once it is capable of being used for the purpose for which it was constructed) in a way that prevents the entry of surface water and other foreign materials into the well.

Proper maintenance, including water quality and quantity testing, is a way of ensuring that the well is kept in good working order and may minimize the need for rehabilitation. Proper well maintenance protects the aquifer and the water supply.

Improper Maintenance

A poorly maintained or constructed well can result in the bacterial or chemical contamination of the well water, the aquifer or the natural environment. One of the most common causes of contamination is foreign materials and surface water in the immediate vicinity of a well having direct access into the well. For example, surface water and other foreign material contamination can occur if the annular seal around the outside of the casing is not watertight, if there are openings in the casing or well cover, or if casing joints are not made waterproof.

Once problems are encountered with a well, it may be possible to rehabilitate it; however, this is not always the case. Well owners should be aware that there are many instances when improper maintenance, no usage, an elevated substance identified in a water quality test or natural gas may require a well to be abandoned in accordance with the *Wells Regulation*.

Reminder: See Chapter 14: Abandonment: When to Plug & Seal Wells and Chapter 15: Abandonment: How to Plug & Seal Wells.

The Maintenance Program

The maintenance program is a plan or protocol that should be in place for any site with a well. The maintenance program is intended to identify issues and potential problems and rectify these as soon as possible.

Well Repair Requirements For Persons Constructing Wells

In cases where issues or problems are identified with a well, it will be necessary to rectify the issues by repairing (e.g., altering, developing) the well to ensure that it does not act as a pathway for contamination, and that it remains suitable for its purpose (e.g., drinking water supply).

There are minimum requirements and exemptions under the *Wells Regulation* that apply for repairing or altering wells. See the later "Well Repair Requirements for Persons Constructing Wells" section of this chapter for further information.

Safety Considerations When Maintaining Wells

There are risks associated with well construction and maintenance activities including explosive gases and electrocution. Since most well owners are not familiar with these potential hazards, licensed well technicians, knowledgeable about these hazards, should always be hired to work on the well.

Photographs Of Improper Well Maintenance

The *Wells Regulation* states that the well owner must maintain the well at all times after the completion of the well's structural stage (i.e., once it is capable of being used for the purpose for which it was constructed) in a way that prevents the entry of surface water and other foreign materials into the well.

The photographs in Figures 11-1 to 11-11 provide examples of wells not being properly maintained. In these cases, it is the well owner's legal obligation to either rectify the problem or abandon the well.

Figure 11-1: Dug Well Without Sealed Access And Improper Mounding

Figure 11-1 shows an open access lid on a dug well cover. The open lid is allowing slugs to enter the well (see Figure 11-2). The ground is not sloped away from the well to prevent ponding around the well. Even if the access lid was properly closed, surface water potentially containing pathogens and other foreign materials can still migrate through the unsealed opening (crack) between the access lid and cover and impair the well water.

Figure 11-2: Slugs Entering An Improperly Sealed Dug Well

This is the inside view of same well shown in Figure 11-1. Slugs have entered through the large opening in the well access lid and are living just below a joint between two concrete casings and just above the water level in this well. The well water is intended to be used for human consumption. The slugs are also leaving waste behind on the casing wall.

Figure 11-3: Water Seeping Through The Unsealed Joints Between Concrete Casings

Figure 11-3 shows the inside view of a well. Water is seeping through the unsealed joints between concrete well casings. The water is leaving marks on the concrete tiles as it moves. The unsealed joints are allowing surface water and other foreign materials, potentially containing potential pathogens, to enter the well and impair the quality of the well water. At the bottom of the photograph, the top of the water level is observed. There is debris and other foreign material floating on top of the water that may impair the quality of the well water.

Figure 11-4: Dug Well Casing With Small Hole

The centre of Figure 11-4 shows a 2 centimetre diameter hole that penetrates through the well casing of a dug well used for human consumption. The hole is located close to the ground surface. The ground surface is not properly sloped and can allow for ponding of surface water adjacent to the well. The hole provides a pathway for surface water and foreign materials such as insects, rodents and snakes to access the well and impair the quality of the well water.

Figure 11-5: Well With Water Ponding

Figure 11-5 shows ponded water that potentially contains pathogens located immediately beside the well. Ponded water can migrate downward through soil pores and bedrock fractures and along the side of the well casing by gravity. The ponded water can enter and impair the quality of the well water. Figure 11-5 also shows an older style non-vermin-proof well cap removed from the well and placed in the ponded water. Any pump equipment installation, repair work or other alterations would require this well cap to be replaced with a vermin-proof well cap.

Figure 11-6: Drilled Well Casing With Hole In Cap

Figure 11-6 shows a 3 cm. square hole in a well cap on top of a drilled well casing. A waterline extends out of the open hole. The open hole in the cap provides a pathway for surface water and foreign materials such as insects, rodents and snakes to access the well and impair the well water.

Figure 11-7: Drilled Well With Opening Between Well Cap And Conduit

Figure 11-7 shows a drilled well with a tape measure on top of a well cap. An open hole exists between the well cap and the white electrical wires and black conduit (on left side of well casing). It is likely that the top of the black conduit has slid down from the well cap over time to create the opening at the well cap. The opening (circled) provides a pathway for foreign materials such as insects, rodent and snakes to access the well and contaminate the well water.

Figure 11-8: Poorly Sited Well That Has Not Been Maintained

In this figure, there is a pond in the foreground. A black coloured goat is sitting on top of a well cover in the centre of the photograph. The well cover is not secured to the well casing and is not watertight. The well cover is bending downward likely due to the weight of animals lying and standing on the well cover. The well cover creates a safety hazard for the animals. Animal waste from the goats sitting on the well cover can also migrate through the well cover and impair the quality of the well water.

Figure 11-9: The Inside Of A Dug Well With A Tree Root Penetrating The Concrete Casing

The dug well in this figure is used for human consumption. The dug well has concrete tile as casing. Below the water level, a tree root is extending from the right side of the photograph. The tree root has penetrated the casing joint (not shown). The tree root is an indicator that the well casing is not sealed. Thus, the unsealed concrete tile joints can permit foreign materials into the well that can impair the quality of the well water.

Figure 11-10: A Poorly Maintained Well Pit

Figure 11-10 was taken looking into a well pit. The concrete tile of the well pit is shown in the centre and upper portion of the photograph. The floor of the well pit consists of gravel and broken limestone bedrock. The sanitary seal of the top of the drilled well is located flush with the floor of the well pit. Two waterlines and an air vent extend out of the drilled well's sanitary seal. There is an open hole in the well pit's concrete tile. A white to tan coloured fungus (foreign material) has been allowed to grow in the pit from the concrete hole and onto the floor. The fungus is also an indicator that surface water can enter the pit. If surface water fills up in the well pit, it could migrate through the air vent and into the well. Fungus and other foreign materials can potentially migrate from the pit into this drilled well that is used for human consumption.

Figure 11-11: Unsealed Concrete Joints And Animal Tied To Well

The centre of Figure 11-11 shows the concrete tiles and lid of a dug well. The joint between the first and second concrete tiles is broken and not sealed. The unsealed joint creates a pathway for foreign materials to enter the well. Also a dog, tied to the top of the well cover, is shown on the right side of the photograph near a tree. There is a potential for animal waste to be discharged near or on the well. Animal waste can migrate to and impair the well water used for human consumption.

General Maintenance For Well Owners

Proper maintenance by the well owner requires ongoing observation of the state of the well, the pumping and other equipment associated with the well and the surrounding area. The owner of the land is responsible for the maintenance of every well located on the owner's property. A well maintenance checklist and some solutions are found in Table 11-1.

Download Table 11-1: Well Maintenance Checklist Items

Reminder: Where existing well pits are in use, they should be regularly inspected and must be properly maintained just like a well. Well pits are prone to collect surface water and other foreign materials. Any surface water or foreign materials that collect in a well pit can potentially access the well through the top of the well. If surface water or other foreign materials are entering a well pit, the well including the well pit must either be properly plugged and sealed or upgraded to prevent the surface water and foreign materials from entering the well.

Reminder: Well owners should review the safety considerations at the end of this chapter when conducting assessments of their wells.

Testing The Water

Groundwater quality in Ontario is generally quite good. However, as part of protecting a drinking water supply, it is important to know the well's water quality and to monitor its changes.

Bacterial Testing

Routine water quality testing is an important aspect of well maintenance for a well owner. A well owner should submit a water sample at least three times each year, or more frequently if a problem is suspected, to:

- the Public Health Unit,
- an Ontario Public Health laboratory (in a bottle supplied by the Ontario Agency for Health Protection and Promotion), or
- a private licensed laboratory for indicator bacteria (total coliform and E. coli) testing.

The bacterial quality of water cannot always be determined from a single sample. To establish bacterial drinking water quality, the well owner should submit 3 samples at least one week apart. Even if the well shows acceptable total coliform and E. coli results, it is recommended that samples be taken and analyzed at least three times a year. One of these samples should be taken in the early spring.

Reminder: See "Sampling and Analyzing Well Water" section, Table 8-9 in Chapter 8: Well Disinfection for information on groups involved in bacterial sampling and testing.

Repeated detection of bacteria in the well water samples means that there is a source of bacteria affecting the well water (e.g., surface water, septic system, manure storage, animal exercise yards or fields where manure is spread). In cases of repeated detection of indicator organisms or other contamination, measures should be taken to identify the source and then prevent it from accessing the well. This may include hiring a licensed well technician working for a licensed well contractor, Professional Geoscientist or Professional Engineer to conduct the assessment. If the assessment concludes remediation of the well is required, it is recommended that the well owner retain a licensed well technician. The well technician that is retained, must hold the correct class of licence and work for a licensed well contractor to conduct the recommended rehabilitation of the well. A water treatment specialist may also be consulted to remove the contaminant from the drinking water, however, the problem will not be resolved if water treatment is pursued without identifying and addressing the source of contamination. If water quality interference is suspected, it is important to contact the local Ministry of the Environment and Climate Change district

Reminder: For issues with water that is not potable see Chapter 14: Abandonment: When to Plug & Seal Wells.

Additional Parameter Testing

Water should be tested regularly for additional parameters (e.g., chemical). A well owner should:

- test the water in the well for nitrate annually and other metals and minerals at least every two years. Some common chemical parameters include sodium, chloride, conductivity, colour, turbidity, calcium, magnesium, manganese, hardness, alkalinity, pH, ammonia, nitrite, nitrate, phosphorus, fluoride, uranium, lead, antimony, arsenic, copper, iron, zinc and sulphate.
- test for some common gases such as hydrogen sulphide, methane and radon.

If there is a reason to suspect that there may be a local problem such as nearby spills (e.g., gasoline station leak), landfills, industrial and mining activities, accidents, or land use changes, a well owner should test the water in the well for pesticides, volatile organic compounds (solvents), petroleum hydrocarbon parameters (benzene, toluene, ethylbenzene, xylenes and petroleum hydrocarbon fractions F1 to F4), heavy metals, and radionuclides.

If there is no cause for concern, a general screening of these additional organic chemicals and metals at least every five years will help verify current water quality.

If problems with well water quality are reported by neighbours, or there are changes in taste or visual quality of the water, test the well water for the above bacterial and chemical parameters.

Local public utilities regularly test well water quality of municipal and other communal well supplies. If nearby municipal or communal supplies uncover elevated parameters in the municipal well water, test the well water for the problem parameter.

Water samples should be submitted to a laboratory licensed under the *Safe Drinking Water Act* to analyze the well samples for the chemical and radiological parameters. To obtain accurate results, a well owner needs to follow the sampling and preserving procedures provided by the laboratory or retain the services of a Professional Geoscientist or Professional Engineer to conduct the sampling.

If necessary, a well owner should use a Professional Geoscientist or Professional Engineer to interpret the test results.

Table 8-9 of Chapter 8: Well Disinfection provides the various roles of different groups involved in bacterial testing and interpretation. Some of these same groups can also provide assistance with chemical testing and interpretation.

The Technical Support Document for the Ontario Drinking Water Quality Standards, Objectives and Guidelines June 2003, revised June 2006, PIBS 4449e01 (found on the Ontario website) can also assist in the interpretation of the well water quality.

The Public Health Ontario's website also has information on water quality testing for well owners.

Assessing The Interior Of The Well With Video Technology Equipement

The lack of light and significant depth in many drilled and bored wells may result in unknown problems with the well's structure, pumping equipment, water quantity or water quality because they are hidden from view. To assist in the visual interpretation of the well, video cameras and other equipment can be installed into the interior of a well and linked to video terminals at the surface.

Down-hole video equipment can help assess:

- the well's interior structure including the casing, casing joints and well screen,
- the pump and associated pumping equipment,
- water levels, water producing zones and depth,
- turbidity, colour and sediment problems, and
- biofilm and mineral encrustation problems.

Best Management Practice – Use Down-hole Video Equipment in Assessment of Well Problem

As part of a well assessment for a well problem, well owners, or their consultants, should consider retaining the services of businesses that have down-hole video equipment and who employ persons who have proper experience in installing the equipment and interpreting the video. In some cases, pumping equipment needs to be installed in the well with the video camera to lower the well's water level to inspect the well.

The video should be recorded by the person conducting the inspection and the video should be kept by the well owner for future reference and repairs.

Persons and businesses conducting this work must meet the licensing requirements in Chapter 3: Well Contractors & Well Technicians – Licences, Responsibilities & Exemptions to determine if they are required to be licensed for this activity.

Well Repair Requirements For Persons Constructing Wells

Requirements For Repairs And Alterations On Existing Wells

Unless exempt, if a person performs a repair on an existing well and during the course of the repair, the person performs any type of well construction activity, then the person must:

- meet the requirements for existing wells found in the *Wells Regulation*, and
- hold a valid well technician licence of the correct class and hold, or work for someone that holds, a valid well contractor licence.

Construct
: when used with respect to a well, means bore, dig, drill or otherwise make, extend or alter. "Construct" also includes installing equipment in or connected to a well (see Chapter 2: Definitions & Clarifications, Table 2-1).

Requirements for the construction of new wells are found in sections 12 (location of wells), 12.4 (well depth), 13 (casing), 14, 14.1 to 14.5 (annular space), 14.8 (development) and 14.11 (tags) of the *Wells Regulation*. Except for well tagging (see Chapter 13: Well Records, Documentation, Reporting & Tagging), these requirements will typically not apply to persons repairing or altering existing wells. For example, new well construction requirements do not apply when a person constructing a well:

- Conducts a minor alteration on an existing well (see "Minor Alteration" in Chapter 2: Definitions & Clarifications, Table 2-1 and "Routine Repair" in Chapter 2: Definitions & Clarifications, Table 2-2)
- Replaces a pump or associated pumping equipment such as a pitless adapter or pitless unit into an existing well
- Extends a well casing above the ground surface
- Installs a new length of casing (commonly called a casing sleeve or liner) inside the well
- Removes a portion or section of well casing from the well.

Reminder: A well is considered to be a "new well" at the time when the initial hole (well) is constructed. See the definition of "new well" in Chapter 2: Definitions & Clarifications, Table 2-2.

Reminder: Equipment used in the re-development of an existing well, such as hydraulic fracturing, and other equipment installed in an existing well for rehabilitation purposes is not considered to be a routine repair. As such, this activity is an "alteration" to a well that is not a "minor alteration". This includes situations where the equipment is installed permanently or temporarily into a well.

Reminder: If an existing well is being altered (other than a minor alteration or pump and equipment installation) some regulatory requirements do apply. For example, the person constructing the well must complete a well record for the alteration (see Chapter 15:

Well Records, Documentation, Reporting & Tagging).

Reminder: If an existing well without a well tag is being altered (other than a minor alteration) some tagging requirements apply (see Chapter 15: Well Records, Documentation, Reporting & Tagging). If an existing well with a broken, defaced, illegible, or otherwise unusable well tag is being altered (including a minor alteration) some tagging requirements apply (see Chapter 15: Well Records, Documentation, Reporting & Tagging).

Reminder: If an assessment determines that a repair or upgrade (alteration) of the well is required, it is recommended that the well owner retain a licensed well technician. The well technician that is retained must hold the correct class of licence and work for a licensed well contractor to conduct the recommended repair or upgrade of the well.

Some registered professionals (e.g., P. Eng, P. Geo, C.E.T.) working for licensed well contractors are exempt from the well technician licensing requirements for certain specified well construction activities (see Chapter 3: Well Contractors & Well Technicians – Licenses, Responsibilities & Exemptions).

Although the *Ontario Water Resources Act* allows a residential well owner to repair or upgrade (alter) his/her own well without a licence, if remuneration takes place (i.e., any form of compensation), or if the land owner is a business corporation, partnership, sole proprietor or a government agency, the land owner must retain a licensed well contractor and employ licensed well technicians of the correct class to alter or repair the well.

Reminder: To determine which prescribed well technician licence class applies to the type of work being performed on an existing well see Chapter 3: Well Contractors & Well Technicians – Licences, Responsibilities & Exemptions.

Alterations Not Considered Minor Alterations

Unless exempt, the person performing an alteration to a well must meet, as a minimum, the maintaining field notes (section 12.1), covering the well (section 12.2), surface drainage (section 12.3), flowing well (section 14.7), well yield (sections 14.9 and 14.10), well tagging (section 14.11), venting (section 15.1), equipment connections (section 15.2), caps and covers (section 15.2), clean equipment (section 15.3), natural gas and mineralized water reporting (section 16), providing the well purchaser with information (section 16.1), well record (section 16.3) and casing height maintenance [subsection 20(2)] requirements found in the *Wells Regulation*.

Minor Alterations

There are some requirements in the *Wells Regulation* that will apply also to a "minor alteration" such as removing a well cap. Unless exempt, the person performing a "minor alteration" to a well must meet, as a minimum, the maintaining field notes (section 12.1), covering the well (section 12.2), surface drainage (section 12.3), flowing well (section 14.7), well tagging for broken or defaced well tags (section 14.11), venting (section 15.1), equipment connections (section 15.2), caps and covers (section 15.2), clean equipment (section 15.3), natural gas and mineralized water reporting (section 16), and casing height maintenance [subsection 20(2)] requirements found in the *Wells Regulation*.

Reminder: If a person performs a "minor alteration" on a well, unless exempt, the licensing requirements apply (see Chapter 3: Well Contractors & Well Technicians – Licenses, Responsibilities & Exemptions).

Extension Of Well Casing For A Well In A Well Pit

If an alteration involves the extension of a well casing above the ground surface for a well in a well pit, the well owner will need to decide if the well pit is to be maintained or abandoned. The person constructing the well and the well owner should also consider following the "Best Management Practice – Well Casing Extensions" for determining the appropriate height for the well casing above the ground surface.

If the well pit is to be maintained, then the person constructing (altering) the well must ensure surface drainage is such that water will not collect or pond in the vicinity of the well, including in the well pit. If the well pit cannot be maintained such that surface water and other foreign materials are prevented from entering the well, then the well pit must be abandoned.

If the well pit is to be abandoned, the person abandoning the well (often the well owner) must ensure the well pit is abandoned, with necessary modifications, as if it were a well. See Chapter 15: Abandonment: How to Plug & Seal a Well for further information.

Best Management Practice – Consider Abandoning Well Pits at the Time of Well Casing Extension

Where a well pit is present, a well owner should consider abandoning the well pit if the well casing is extended above the ground surface. If abandoned, the well pit must be abandoned in accordance with the *Wells Regulation* requirements that are presented in

Chapter 15: Abandonment: How to Plug & Seal a Well. Properly abandoning the well pit will reduce well maintenance issues and reduce the risk of surface water and foreign materials entering the well.

Reminder: To determine which prescribed well technician licence class applies to the types of work being performed on an existing well see Chapter 3: Well Contractors & Well Technicians – Licenses, Responsibilities & Exemptions.

Installing Used Equipment During Well Repair

The *Wells Regulation* allows for the installation of used pumps, pumping equipment, vents, cover, caps, pitless adapters, pitless units and other equipment in wells.

The *Wells Regulation* - All new or used equipment installed in, or connected to, a well must be clean and must not impair the quality of the well water or aquifer. Well owners must maintain installed equipment to ensure it does not impair the quality of the well water.

Best Management Practice – Ensuring Equipment is New and Chlorinated

In addition to the requirement that equipment be clean and free of contamination, anyone working on an existing well should:

- install new parts, devices and materials in drinking water wells that are certified to meet the National Sanitation Foundation (NSF) International Standard 61 “Drinking Water System Components - Health Effects”. Verify the components are certified by searching NSF/ANSI Standard 61 [1] Approved Drinking Water System Components database and by looking for the NSF logo on the equipment,
- install parts, devices and materials that are suitable for the particular type of environment and well,
- clean and sanitize the parts, devices, materials and well construction equipment with chlorinated water as recommended in the “Sanitary Practices” section in Chapter 8: Well Disinfection, and
- ensure parts are installed to the manufacturers' specifications,

Casing Height When Preforming Work On Or Near A Well

The *Wells Regulation* - Persons, including well owners, should be aware of the following *Wells Regulation* requirements when performing any routine well maintenance, repair or alteration, or when performing other work such as landscaping around a well:

- Where a casing height extends ≥40 cm (16 inches) above the ground surface, the top of the casing must not be reduced to a height of ≤ 40 cm (16 inches) above the ground surface.
- Where the well is an existing well and the casing height extends ≤ 40 cm (16 inches) above the ground surface, the top of the casing must not be reduced to a height of less than the original casing height.

Reminder: The casing heights above do not apply to wells constructed by the use of a driven point or jetted point wells as long as they meet the minimum requirements of the *Wells Regulation*. For further information see the section titled: “Casing Height and Mounding,” of Chapter 7: Completing the Well’s Structure.

Reminder: To determine which prescribed well technician licence class applies to raising the well casing height on an existing well see Chapter 3: Well Contractors & Well Technicians – Licenses, Responsibilities & Exemptions.

Best Management Practice – Well Casing Extensions

A person extending a well casing above the ground surface in an existing well should:

- consider the methods, materials and installation techniques outlined in the Best Management Practice titled “Ensuring Equipment is New and Chlorinated” on page 24 of this chapter,
- meet or exceed the new well requirements for the height of the well casing and annular space in the *Wells Regulation*,
- extend the top of the casing above the known height of any anticipated flood level, and
- consider the final grade of the ground surface around the well to direct surface water runoff away from the well.

Safeguarding The Well Tag

The *Wells Regulation* - It is not permitted to deface, alter, conceal or obstruct a well tag.

The *Wells Regulation* - It is not permitted to remove a well tag that is affixed to a well unless the:

- person has the written consent from the Director;
- well tag on the well that is being altered is broken, defaced, illegible or otherwise unusable; or
- well is being altered or abandoned (plugged and sealed).

The *Wells Regulation* - It is not permitted to use a well tag issued by the Ministry except in accordance with the *Wells Regulation*.

The *Wells Regulation* - During alterations to a cased well with a well tag, the well tag must be safeguarded and, if removed, it must be re-affixed permanently to the outside of the casing or to a permanent structure associated with the well, upon completion of the alteration.

Reminder: Any damaged well tags must be returned to the Ministry and be replaced. See Chapter 13: Well Records, Documentation, Reporting & Tagging for further information.

Well Problems And Rehabilitation

Any damaged well tags must be returned to the Ministry and be replaced. See Chapter 13: Well Records, Documentation, Reporting & Tagging for further information.

Reminder: Table 11-2, below, contains only some examples of common causes of well problems and rehabilitation techniques and may not apply to all wells. As each well and environment is different, a Professional Engineer or a Professional Geoscientist should assess the well and well water to identify the source of the problem and provide recommendations on a case by case basis. In some cases, a licensed well technician with the correct class of licence working for a licensed well contractor can conduct the assessment of the well. If the assessment concludes remediation of the well is required, it is recommended that the well owner retain a licensed well technician. The well technician that is retained must hold the correct class of licence and work for a licensed well contractor to conduct the recommended rehabilitation of the well. It is important to retain properly licensed persons where electrical or plumbing work is necessary. Where water treatment is deemed necessary or is advised, it is recommended that a professional water treatment expert install any water treatment devices on the building's plumbing. It is important that water treatment devices are maintained in accordance with manufacturers' specifications to ensure effective operation.

Table 11-2: Examples Of Common Well Problems, Possible Casues And Rehabilitation Techniques

Problem	**Potential Cause**	**Possible Action/Rehabilitation**
Foreign substances in the well (e.g., insects)	• Compromised well cap, well cover, sanitary well seal or casing	• Repair or replace defective components, and then clean and chlorinate the well (see Chapter 8: Well Disinfection)
Pumping equipment failure	• Sediment in the well clogging pumping equipment, well screen and plumbing	• Clean the well (extraction of sediment from the well) and chlorinate the well (see Chapter 8: Well Disinfection) • Install a finer screen or sand pack filter or re-develop the well • Install a sediment filter on the plumbing system • Seal off joint or the bottom of the casing if either area is allowing overburden to enter the well
Pumping equipment failure	• Broken pump or associated parts (e.g., pressure switch)	• Repair or replace pump or parts and chlorinate the well (see Chapter 8: Well Disinfection)
Pumping equipment failure	• Worn or split waterlines, split or exposed electrical cables or frayed electrical cable contacts	• Repair or replace defective components and chlorinate the well (see Chapter 8: Well Disinfection)
Pumping equipment failure	• Short in the electrical panel	• Repair or replace defective components

Problem	Potential Cause	Possible Action/Rehabilitation
Pumping equipment failure	• Drop in groundwater level	• Lower the pump intake and/or deepen the well. For additional rehabilitation techniques see below
Drop in the groundwater level or no water (after verifying pump is in working order)	• Natural causes due to shortages in precipitation to recharge aquifer	• If the cause is natural, lower the pump intake, deepen the well, construct a new deeper well or supplement with alternate storage facilities (e.g., cistern)
Drop in the groundwater level or no water (after verifying pump is in working order)	• Well interference (i.e., impacted from other activities in the area that lower the water table or depressurize the aquifer • Some examples of activities which may cause interference include mine, pit, quarry or construction dewatering, removal of material in a quarry or uncontrolled flowing wells)	• If off-site dewatering is the suspected cause contact the local Ministry of the Environment and Climate Change office
Drop in the groundwater level or no water (after verifying pump is in working order)	• Improper pump selection causing sand movement into the well or bridging	• Check pump against recommendation on the well record to verify that the pump is correctly sized to recommended pumping rate (not the test pumping rate) • In addition to reducing the excessive pumping rate, see Possible Action/Rehabilitation in the "Pumping equipment failure" "Sediment in the well clogging pumping equipment, well screen and plumbing," row above
Reducing flow rates over time	• Certain types of naturally occurring non-harmful bacteria creating slime and particles (e.g., iron oxidizing bacteria) can clog water intakes on pumps or pumping equipment, well screens and bedrock fractures intersected by well • Iron oxidizing bacteria are a form of biofilm	• Use a down-hole video camera to verify problem • Remove and clean the pumping equipment • In some cases removal and replacement of the well screen may be necessary • If biofilm is present, do not highly chlorinate well as biofilm can protect other bacteria and will also significantly harden to the sides of the well • Treat the well by chemical treatment to remove biofilm or mineralization • For biofilm treat the well with acids and biodispersents

Problem	Potential Cause	Possible Action/Rehabilitation
Reducing flow rates over time	• Deposits of calcium and magnesium carbonates, manganese or iron can clog plumbing, water intakes on pumps, pumping equipment, well screens and bedrock fractures intersected by well.	• For dissolution of minerals treat the well with acid such as hydrochloric acid • Examples of re-developing a well: • Hydrofracturing • Surging (see Chapter 7: Completing the Wells Structure) • Jetting with high pressure water • Disinfect the well using the suggested methods found in Chapter 8: Well Disinfection. As part of well disinfection, the total treatment volume should be a pH controlled chlorine dose that is 5 times the volume of the water well column and creates free chlorine residual between 50 to 200 mg/L in the well and nearby aquifer
Reducing flow rates over time	• Natural plugging of the well intake zone from the aquifer either through the filter pack, well screen or water intake fractures with fine sediments over time.	• Hydrofracturing involves sealing areas of the well using one or more packer device(s) followed by the injection of water under high pressure into the sealed area of the well to dislodge and clean out the bedrock's water producing fractures. Hydrofracturing is for drilled wells using bedrock groundwater sources only.
Bacteria identified in well Reminder: If the well is producing total coliforms or E. coli with the raw well water, see Chapter 14: Abandonment: When to Plug & Seal Wells and do not drink raw well water	• Ponding of surface water in the vicinity of the well	• Create a mound around the casing to direct surface water away from the well • Disinfect the well (see Chapter 8: Well Disinfection)
Bacteria identified in well	• Compromised seal around the casing	• Replace the seal • Disinfect the well (see Chapter 8: Well Disinfection)
Bacteria identified in well	• Casing height is below the flood level or below the level where water may be collecting in a well pit	• Extend the casing and install well caps and vents that prevent surface water and other foreign materials from entering well • Disinfect the well (see Chapter 8: Well Disinfection)
Bacteria identified in well	• Casing length too short below ground surface • Surface water and near surface sources of contamination can quickly migrate into the well below the short casing	• Remove short casing and ream hole to proper depth. Install and seal a longer length of well casing that seals off locations where surface water enters well • As an alternative, install and seal smaller diameter casing that is longer than original well casing (typically called a liner). Seal the space between the casings and between the new casing and side of the well with a proper cement or bentonite sealant. The new casing will also seal off locations where surface water enters well • Disinfect the well (see Chapter 8: Well Disinfection)

Problem	Potential Cause	Possible Action/Rehabilitation
Bacteria identified in well	• Separation distance between well and contamination source is too short • The short pathway allows for contaminants to quickly migrate from the source to the well	• Remove sources of contamination or abandon (plug and seal) the well and construct a new well at a location that is significantly farther (and preferably up-gradient) from the source of contamination • Disinfect the well (see Chapter 8: Well Disinfection) • If necessary, add a water treatment device to plumbing such as a chlorination unit, ultra-violet light system or chlorinator-injector units • If the well is producing total coliforms or E. coli with the raw well water, see Chapter 14: Abandonment: When to Plug & Seal Wells
Bacteria identified in well	• Casing, casing joints or cover of well or well pit is not watertight or is cracked • The openings can allow for surface water or other foreign materials to enter the well pit and well	• Seal or replace casing, joints or cover for well or well pit • Disinfect the well (see Chapter 8: Well Disinfection)
Bacteria identified in well	• Well or pumping equipment was not chlorinated	• Clean and Disinfect the well (see Chapter 8: Well Disinfection)
Bacteria identified in well	• Off-site contamination source (e.g., sewage or animal lagoon, manure pile, septic system) impairing the aquifer	• Contact local Ministry of the Environment and Climate Change office to report the contamination • Contact local public health unit for further advice on consuming the well water (see Chapter 8: Well Disinfection) • If necessary add a water treatment device to plumbing such as a chlorination unit, ultra-violet light system or chlorinator-injector units • If the well is producing total coliforms or E. coli with the raw well water, see Chapter 14: Abandonment: When to Plug & Seal Wells
Bacteria identified in well	• Cross contamination through the pumping system or from other source (e.g., lake water, cistern water, storage tank)	• Inspect pumping system for the existence of backflow prevention devices and, if present, determine if they are working properly • Repair or replace defective components • Install backflow prevention devices if not present • Disinfect the well (see Chapter 8: Well Disinfection)
Slimy red, black or grey coloured material in water, well or on pumping equipment	• Certain types of iron bacteria such as Gallionella, Crenothrix and Leptothrix	• Follow the Actions/Rehabilitation suggestions found in the Reducing flow rates over time Problem in this Table
Red or black staining on plumbing fixtures and laundry	• Naturally occurring iron (rusty colour) or manganese (black colour) causing aesthetic colour and taste issues with the water	• Use water treatment devices such as greensand filters, aeration devices and in some cases water softeners

Problem	Potential Cause	Possible Action/Rehabilitation
Scaling on tubs and sinks	• Naturally occurring calcium carbonate minerals are usually associated with wells in limestone bedrock or marble bedrock • Typically known as hardness	• Install water treatment devices such as softeners
Blackish water or blackish flakes associated with well water	• Naturally occurring iron sulphide causing aesthetic colour issues with the water • Sometimes naturally occurring hydrogen sulphide is associated with this problem • The problem can be initiated by the presence of sulphate reducing bacteria	• Follow the Actions/Rehabilitation suggestions found in the Reducing flow rates over time Problem column in this Table • Install water treatment devices such as oxidizing filters, chlorination, ozonation, aeration or activated carbon, depending on the concentration • If gas is present, see Chapter 14: Abandonment: When to Plug & Seal Wells
Salty taste associated with well water	• Naturally occurring sodium and chlorides (or other salt components) causing aesthetic taste issues with the water	• Install water treatment devices such as reverse-osmosis
Salty taste associated with well water	• Road de-icing components entering ground water	• Contact Ministry of Transportation or local road authority to report the road de-icing problem
Salty taste associated with well water	• Salt from a salt storage facility is leaching into the groundwater	• Contact local Ministry of the Environment and Climate Change office to report the contamination
Salty taste associated with well water	• Backwash from water softener or, septic system effluent high in chloride, discharging into the groundwater	• If the backwash discharge source is on-site and is the source of the problem, change the discharge location to another approved location • If the problem is caused by water softener backwash discharge, an alternative is to stop using the water softener • See Chapter 14: Abandonment: When to Plug & Seal Wells if the chloride concentration is greater than 500 mg/L
Laxative effect after drinking water and bad tastes (where bacteria are not present)	• Naturally occurring sulphate causing aesthetic and other issues (e.g., laxative) with the water	• Install water treatment devices such as reverse-osmosis or distillation • If the sulphate concentration is greater than 500 mg/L, see Chapter 14: Abandonment: When to Plug & Seal Wells

Problem	**Potential Cause**	**Possible Action/Rehabilitation**
Rotten egg odour or corrosion	• Low concentrations of naturally occurring hydrogen sulphide gas or sulphate reducing bacteria associated with the groundwater • Sulphate reducing bacteria typically live in anaerobic (non-oxygen environments near the bottom of the well) and will generate hydrogen sulphide gas	• Follow the Actions/Rehabilitation suggestions found in the Reducing flow rates over time Problem column in this Table • If casing has been corroded, rip out (or ream) existing well casing. Install and seal a new length of well casing and fill annular space with suitable sealant as shown in Chapter 5: Constructing & Casing the Well and Chapter 6: Annular Space & Sealing • Install water treatment devices such as oxidizing filters, chlorination, ozonation, aeration or activated carbon, depending on the concentration • If gas is present, see Chapter 14: Abandonment: When to Plug & Seal Wells
Presence of poisonous or explosive gas as observed by the following: • Gas bubbles escaping from well or observed in a clear glass of well water • Milky colour associated with well water • Gas vapours may sometimes be observed coming off the wellhead • Gas vapours may ignite in the well or building	Hydrogen Sulphide • In some cases, naturally occurring elevated concentrations of hydrogen sulphide gas are associated with the groundwater at concentrations elevated above 5 parts per billion range and it is detectable by smell in this concentration range • At highly elevated concentrations, hydrogen sulphide gas smell is deadened and is invisible • At elevated concentrations there is a risk of explosions, poisoning or asphyxiation from hydrogen sulphide • At a concentration of 100 parts per million, hydrogen sulphide is immediately dangerous to life and health Methane • Naturally occurring elevated concentrations of methane gas are associated with the groundwater in many areas of Ontario • At elevated concentrations, methane gas is not detectable by smell and is invisible • At elevated concentrations there is a risk of explosions or asphyxiation from methane Other Gases • There can be other explosive or poisonous naturally occurring gases in bedrock formations which may contain petroleum hydrocarbons	• In some cases, the well must be properly abandoned (properly plugged and sealed) • Use treatment devices, separators and safely vent the entire water system and wellhead • If gas is present, see Chapter 14: Abandonment: When to Plug & Seal Wells • To report the presence of gas, see Chapter 13: Well Records, Documentation, Reporting & Tagging

Problem	Potential Cause	Possible Action/Rehabilitation
Radon gas has been identified	• Due to a natural breakdown of uranium, elevated concentrations of radon gas can be present in soil and bedrock • Radon gas can be poisonous • The gas is odourless and colourless	• In some cases, the well must be properly abandoned (properly plugged and sealed) • Install treatment devices and safely vent the entire water system, basement and wellhead • If gas is present, see Chapter 14: Abandonment: When to Plug & Seal Wells • To report the presence of gas, see Chapter 13: Well Records, Documentation, Reporting & Tagging
Gasoline or fuel oil odour, or rainbow film on water	• Possible gasoline or fuel oil contamination • Sources can be a spill or a leak from underground storage tank and distribution lines or a leak from an above ground storage tank • Rainbow film on water may also be caused by naturally occurring phenols from vegetation	• Contact local Ministry of the Environment and Climate Change office or Spills Action Centre () to report contamination and the local public health unit for advice • Do not drink raw well water • If the source of contamination is on-site, contact your insurance company or professional environmental consultant to identify, remove and clean-up source • Provide temporary drinking water and if necessary install treatment devices on plumbing • In some cases, the well must be abandoned (properly plugged and sealed) • See Chapter 14: Abandonment: When to Plug & Seal Wells if an Ontario Drinking Water Quality Standard, such as benzene, has been exceeded
Sampling analysis shows raw well water producing fluoride	• Naturally occurring minerals associated with Canadian Shield and limestone bedrock deposits • Can result in mottling of children's teeth or in some cases case bone defects	• In some cases, the well must be properly abandoned (properly plugged and sealed) • Do not drink raw well water • Install treatment devices on drinking water such as reverse osmosis or distillation • See Chapter 14: Abandonment: When to Plug & Seal Wells if an Ontario Drinking Water Quality Standard such as fluoride has been exceeded
Sampling analysis shows raw well water producing elevated uranium, arsenic or other metals exceeding the Ontario Drinking Water Quality Standards	• Naturally occurring minerals associated with Canadian Shield bedrock deposits • Nearby industrial discharges	• Contact local Ministry of the Environment and Climate Change office or Spills Action Centre () to report contamination and the local public health unit for advice • Do not drink raw well water • Provide temporary drinking water and if necessary install treatment devices on plumbing • In some cases, the well must be abandoned (properly plugged and sealed) • See Chapter 14: Abandonment: When to Plug & Seal Wells if an Ontario Drinking Water Quality Standard such as uranium or arsenic have been exceeded

Problem	Potential Cause	Possible Action/Rehabilitation
Sampling analysis shows water producing elevated lead	• Naturally occurring minerals associated with bedrock deposits • Nearby industrial discharges • Old plumbing pipe and solder to seal plumbing joints • Materials used to seal well screens in older wells (e.g., packers)	• Contact local Ministry of the Environment and Climate Change office or Spills Action Centre () to report contamination and the local public health unit for advice • Do not drink raw well water • Provide temporary drinking water and if necessary install treatment devices on plumbing • In some cases, the well must be properly abandoned (properly plugged and sealed) • See Chapter 14: Abandonment: When to Plug & Seal Wells if the Ontario Drinking Water Quality Standard for lead has been exceeded
Flood water entering the well	• Natural precipitation or snowmelt events causing rivers, lakes and streams to flood area	• Flood water contains potential pathogens. Pathogens may have entered the well during the flood event • Do not use the well until flood water has left the area; the ground has become unsaturated; and; the well has been rehabilitated • After the flood event, assess the well to ensure the structure is intact. Older hand dug wells constructed with stone may be very unstable due to saturated ground conditions and may need to be plugged and sealed • Upgrade the well by altering it to prevent flooding water from entering the well. There are vents and caps that can prevent flood water from entering the well (see Figure 9-12 and Figure 9-29 in Chapter 9: Equipment Installation) • Disinfect the well (see Chapter 8: Well Disinfection) • If necessary install treatment devices such as ultraviolet lights or chlorinators if bacterial contamination remains • If the well is producing total coliforms or E. coli with the raw well water, see Chapter 14: Abandonment: When to Plug & Seal Wells

Best Management Practice – Well Rehabilitation Literature

In addition to Table 11-2 the following books provide further information on the rehabilitation of wells including biofilm and mineralization problems:

Schnieders, John H. 2003. Cleaning, Disinfection and Decontamination of Water Wells. Johnson Screens Inc., St. Paul, MN, ISBN 0-9726750-0

Mansuy, Neil. 1998. The Sustainable Well Series - Water Well Rehabilitation: A Practical Guide to Understanding Well Problems and Solutions. Layne Geosciences Inc. /CRC Press. ISBN10: 1566703875, ISBN13: 9781566703871

Safety Considerations When Maintaining Wells

There are many serious dangers associated with wells that must be considered when maintaining and rehabilitating well. Important precautionary actions to take include:

- making sure that the power supply to the pump has been shut off to minimize the risk of shock or electrocution when inspecting a well,

- safeguarding the well site any time the well cap or cover is removed to minimize hazards, and
- following all applicable safety plans for the site.

Reminder: A person must not enter any confined space (e.g., non-ventilated areas including well pits, pump house, and others defined in the *O. Reg. 632/05* under the *Occupational Health and Safety Act*) unless properly trained and equipped. Confined spaces present asphyxiation hazards and some wells produce naturally occurring gases that may be poisonous and/or explosive.

When maintaining wells, well owners should be made aware of the many serious risks associated with wells including explosive gases and electrocution. Since most well owners are not familiar with these potential hazards, licensed well technicians, knowledgeable with respect to these hazards, and working for licensed well contractors should always be hired to work on the well. See Chapter 3: Well Contractors & Well Technicians – Licenses, Responsibilities & Exemptions for further information on licensed well contractors and well technicians.

It is important that anyone working on a well:

- obtain and follow the guidelines set out in the Material Safety Data Sheet (MSDS) for any chemical product used in the rehabilitation. The MSDS will include the following:
  - properties of the material,
  - hazards associated with the material,
  - personal protective equipment (PPE) required when using the material,
  - contact information, and
  - first aid and medical attention information.
- make sure that all rehabilitation products are approved for the intended use and will not impair the quality of the groundwater.
- check product labels to verify product contents, proper use and storage

Reminder: Safety practices and requirements (e.g., Workplace Hazardous Materials Information System training), as regulated and advocated by the Ministry of Labour, must be followed.

12. Flowing Wells

Chapter Description

This chapter describes flowing wells [1] and how to predict the likelihood of encountering a flowing well. This chapter also discusses how to address flowing conditions when a well is constructed. Due to the serious consequences, such as flooding and property destruction that can result from uncontrolled flowing wells, additional resources including experienced professionals and publications should be consulted if flowing conditions are likely to be encountered.

Regulatory Requirements - Flowing Wells

Relevant Sections - The *Wells Regulation*

- Flowing Well Definition – Subsection 1(1)
- Flowing Wells – Section 14.7
- Disinfection Exemption - Subsection 15(14)
- Venting – Section 15.1
- Abandonment – Section 21.1

The Requirements - Plainly Stated

The *Wells Regulation* requires the following when a flowing well is encountered:

Construction and Device

- the person constructing the well must ensure that the well is constructed to accommodate and be compatible with a device that:
  - controls the discharge of water from within the well casing,
  - is capable of stopping the discharge of water from within the well casing,
  - is capable of withstanding the freezing of water in the well casing, and
  - is installed on or in the well.

- the construction of the well and the device installed must prevent any:
  - uncontrolled flow of water from the well or at the well site, and
  - backflow of water into the well or well casing.

Abandonment Option

The requirements listed above do not apply if the well is abandoned according to the *Wells Regulation* (for further details see Chapter 15: Abandonment: How to Plug & Seal Wells).

Costs

Every contract between the well purchaser and the well contractor for the construction of a well is deemed to contain a term that makes the well contractor responsible for the costs of:

- complying with the above requirements, and
- abandoning the well, if applicable.

This is the case irrespective of whether the contract is written or verbal or whether this responsibility is explicitly written into the contract or not. The only exception is if there is a written contract between the well contractor and well purchaser that specifically releases the well contractor from these costs.

Venting

If a pump is installed in a new or existing flowing drilled well, the person constructing the well must install an air vent on the upper end of the casing that allows for an equalization of pressure between the inside of the well casing and the atmosphere. The vent must also allow for the release of all gases from the well. The air vent must meet the minimum size, length and shielding requirements found in the Plainly Stated section of Chapter 9: Equipment Installation.

Venting Exemption

A new well in which the casing is used to transmit water out of the well (e.g., flowing well without a well pump) does not need to meet the above air vent requirements.

Chlorination Exemption

The disinfection requirements, found in Chapter 8: Well Disinfection, do not apply to a “flowing well”.

flowing well
: means a well that has a static water level above the ground surface.

static water level
: means the level attained by water at equilibrium in a well when no water is being taken from the well.

Relevant Sections - Additional Regulations Or Legislation

Fisheries Act, R.S.C. 1985, Chapter F-14.

Ontario Water Resources Act. R.S.O. 1990, Chapter O.40: Sections 30 (Impairment) and 34 to 34.2 (Permit To Take Water)

Ontario Water Resources Act. R.S.O. 1990, Chapter O.40: *Ontario Regulation 387/04: Water Taking*

Key Concepts

What is A Flowing Well?

A “flowing well” means a well that has a static water level above the adjacent ground surface. Flowing wells occur when water pressure in the aquifer causes the water level to rise above the ground surface.

There are several things that are important to know with respect to flowing wells:

- In the majority of cases, only confined aquifers hold the potential for flowing wells
- Strong artesian (hydrostatic head) pressure forces groundwater above the ground surface to create a flowing well (see Figure 12-1)
- There are specialized construction techniques and devices that are used when constructing a well in flowing conditions to control the free flow of groundwater from the well
- Improper construction can lower the aquifer's hydraulic pressure, waste groundwater and create flooding problems
- Elevation and loadings (e.g., recharge, discharge) are two hydrogeological factors that create conditions for the development of flowing wells (see Figure 12-3)
- Aquifer recharge events and groundwater withdrawals affect the groundwater level which may lead to intermittent flowing conditions

Figure 12-1: A Flowing Well

Figure 12-1 shows a flowing well discharging groundwater above the top of the well casing and causing a flooding problem.

Figure 12-2: A Flowing Well

Figure 12-2 shows another flowing well discharging groundwater above the top of the well casing.

Figure 12-3: Geological Conditions That Create Flowing Wells

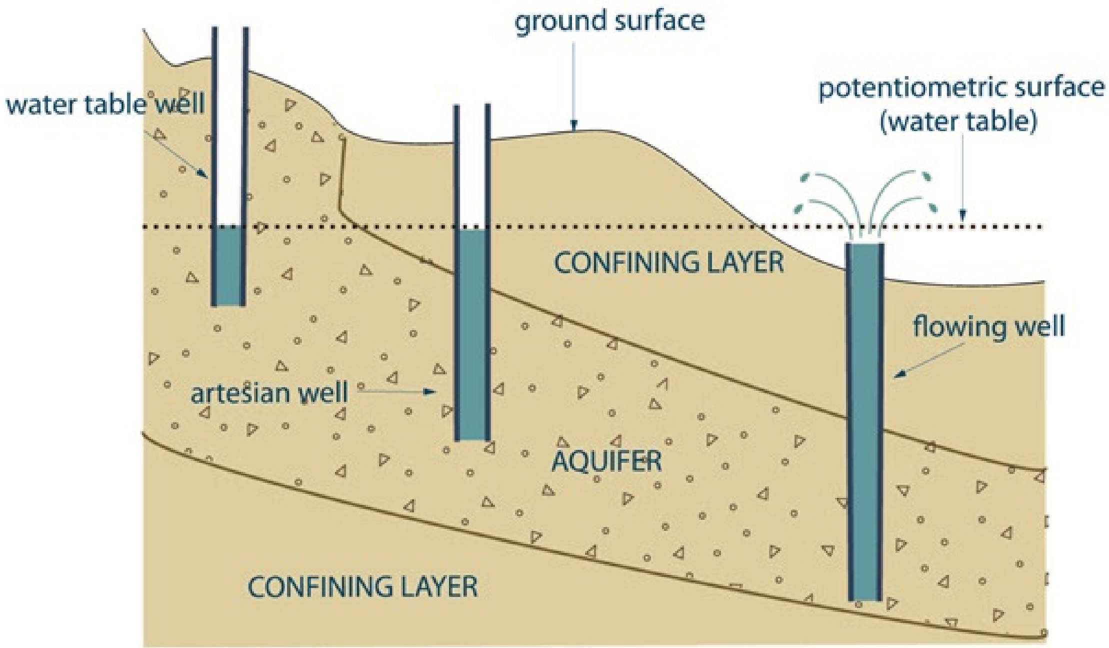


Figure 12-3 is a cross-section diagram explaining the geological conditions that cause flowing wells. The ground surface and geological units in the subsurface are shown to slope downward to the right.There are three wells that have been constructed into the subsurface.

The well on the left has been constructed into a sand and gravel subsurface material. There is a confining layer (for example clay or silt) below the sand or gravel subsurface material. As a result, water from precipitation will migrate down through the sand and gravel from the ground surface and collect in the sand and gravel forming an aquifer. The top of the aquifer is called the water table. As there is no pressure exerted by a confining material on top of the sand and gravel, the water level in the well is exactly the same as the potentiometric surface (or water table). This type of well (on the left) is called a water table well.

The well in the centre has been constructed through a confining layer (for example, clay or silt) and is completed into the sand and gravel subsurface material that contains the aquifer. The weight of the upper confining layer exerts a positive pressure on the water aquifer in the subsurface. When the well in the centre is constructed through the confining layer into the aquifer, the positive water pressure is released causing the water to rise up the hole until the water level reaches the same pressure as the atmosphere. As the water level is above the actual level of the aquifer, the potentiometric surface (water table) is shown to be above the actual location of the aquifer at and around the well in the centre. This type of well (in the centre) is called an artesian well.

The well on the right has been constructed in a similar fashion as the well in the centre; however, the ground surface at the well on the right is at a significantly lower elevation than the well in the centre. As positive pressure in the aquifer is the same in both wells, the potentiometric surface (or water table) is actually above the ground surface at the location of the well on the right. When the water level rises in the well to achieve an equal pressure with the atmosphere, the water pressure causes the water to flow out of the well onto the ground surface. This type of well (on the right) is called a “flowing well”.

Why Regulate Flowing Wells?

It is essential to control flowing wells to:

- conserve groundwater resources,
- prevent adverse effects to the natural environment such as property damage, flooding, sediment deposition, erosion and surface water impacts,
- preserve the pressure within the aquifer, and
- prevent the creation of a direct pathway for contaminants.

Construction Considerations When Flowing Conditions Are Encountered

There are several factors that should be considered (see Table 12-1 below) when predicting the occurrence of flowing well conditions and when constructing wells in areas where flowing conditions may occur. Details are provided on the following pages.

Table 12-1: Important Considerations

Phase	Consideration

Phase	Consideration
I. Predicting	1. Analyzing the Surrounding Physical Setting and Local Knowledge 2. Examining Well Records and Existing Hydrogeological Reports
II. Designing	3. Determining Geologic conditions 4. Determining Depth, pressure and flow of aquifer 5. Determining Well construction equipment and site specific design

I. Predicting A Flowing Well

The following provides two ways to predict the likelihood of a flowing well.

Consideration 1: Analyzing The Surrounding Physical Setting And Local Knowledge

Possible indicators of a flowing well include a valley location or areas where nearby surface water is at a higher elevation than the area of the proposed well site. The person constructing the well should check for other flowing wells and "springs" in the area. Visible flow at the surface or wet soil conditions may be indicators of flowing well conditions. The person constructing the well or local residents may have general knowledge of the area that suggests possible flowing well conditions.

Consideration 2: Examining Well Records And Existing Hydrogeological Reports For The Area

Obtaining well records from the Ministry of the Environment and Climate Change (see the Resources section of this manual) for nearby wells is an important step in understanding the types of aquifers in the area and should be done prior to beginning construction. In addition, in some areas of Ontario, hydrogeological reports have been produced to identify aquifers that may produce flowing wells. These hydrogeological reports may be found at the local office of the:

- Ministry of the Environment and Climate Change
- Municipality
- Conservation Authority

II. Designing A Flowing Well

For each type of geology, and depending on the type of construction equipment, there are factors that should be considered to ensure an efficient flowing well (see Table 12-1 and design considerations 3, 4 and 5 below).

Best Management Practice – Planning to Control the Flow

Prior to beginning construction in a region known to have flowing well conditions, it is essential that a plan be in place to control the flow. The person constructing the well should consider retaining a Professional Engineer or Professional Geoscientist (consultant) experienced in hydrogeology and flowing well conditions to design the well. If the person constructing the well is unfamiliar with the area or with flowing well conditions, it is important that a licensed well contractor and well technician (of the correct class) experienced with flowing wells be consulted. In some cases, installing a small pilot hole may be appropriate to determine subsurface conditions.

Consideration 3: Determining The Geologic Conditions

To properly design the well, the geological and hydrogeological environment has to be assessed. This knowledge will determine the best construction process for the well. For example, two different environments requiring different well designs are as follows:

- Competent bedrock has been encountered and a sufficient length of casing has been installed. The person constructing the well may need to seal the casing into the bedrock with a proper concrete grout to ensure flowing water will not rise up through the annular space of the well. The person constructing the well would then continue to advance the smaller diameter hole inside the casing down to the artesian aquifer in the bedrock.

- A thick [e.g., 30 m (100ft)] clay layer has been encountered above a sand and gravel formation (artesian aquifer). The person constructing the well may need to advance a large diameter hole and casing to just above the top of the aquifer. Next, the person constructing the well may need to seal the annular space of the larger diameter casing into the clay and then advance a smaller diameter hole and casing through the larger casing into the aquifer. Finally, the person would install a seal between the two casings to ensure flowing water will not rise up through the annular space between the well casings.

Consideration 4: Determining Depth, Pressure And Flow Of Aquifer

The location of the recharge zones, thickness of confining layers, elevation of the ground surface and physical characteristics of the aquifer will determine the likelihood of encountering flowing well conditions. A person constructing a well should accurately determine this information or plan for the worst case scenario.

Important Definitions [2] are:

Piezometric level
: The level to which groundwater in a confined aquifer will rise within a well when no water is being taken from the well. It is the same as the static water level (see Chapter 2: Definitions & Clarifications, Table 2-1). In the case of a flowing well, the piezometric level is above the ground surface. It is not possible to look at the volume of an artesian well discharge and determine the elevation of the piezometric level. The piezometric level is expressed in metres (or ft) above ground surface.

Artesian head
: 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 kilopascals (kPA) or pound force per square inch (psi)], is the artesian head.

Downhole hydrostatic head pressure (or DHHP)
: The hydrostatic pressure at the top of the artesian aquifer, which results from the combination of the artesian head and a water column extending from the top of the artesian aquifer to the ground surface [expressed as kilopascals (kPA) or pound force per square inch (psi)].

Downward grout pressure (or DGP)
: The pressure that must be exerted by the grout (sealant) in order to equalize the DHHP [expressed as kilopascals (kPA) or pound force per square inch (psi)] and stop the flow.

Determining Pressures and Elevations:

Determining pressures and elevations involves measurement, calculations and observations.

Reminder: When using metric units, the exact pressure conversion from 1 m of height of water equals 9.8 kPa.

Artesian Head and Piezometric Level (or Static Water Level)

Two methods for measuring artesian head (static water level) are as follows:

1. Installing a pressure gauge on top of the enclosed casing (see Figure 12-5)

   Reading the gauge will provide a measurement in either kilopascals (kPa) or pounds force per square inch (psi). This will provide the artesian head.

   To convert the pressure readings to distance the following conversions are important:

   1 kPa equals 0.1 m or
   1 psi equals 2.31ft

   Multiplying the artesian head kPa pressure reading by 0.1 m (or the psi pressure reading by 2.31ft) will provide the elevation of the piezometric level (or static water level) in metres (or ft) above the elevation of the pressure gauge.

   piezometric level (metres) = artesian head (kPa) × 0.1 (m/kPa)
   piezometric level (ft) = artesian head (psi) × 2.31 (ft/psi)

   Measuring the distance between the elevation of the pressure gauge to the ground surface and then adding the result to the calculated piezometric elevation will provide the piezometric (static water level) elevation above the ground surface.

2. Installing a casing extension to contain the flowing water

The water level inside the extended casing above the ground surface is measured. The result will provide the piezometric level (static water level) in metres (ft) above the ground surface.

To convert the height measurement of a water column to pressure the following conversions are used:

1 m equals 10.0 kPa
1 ft equals 0.433 psi

Multiplying the piezometric level (or static water level) by 10 kPa (or 0.433 psi) will provide the artesian head pressure in kPa (or psi) above the ground surface.

artesian head (kPa) = piezometric level (m) × 10 (kPa / m)
artesian head (psi) = piezometric level (ft) × 0.433 (psi / ft)

As an alternative, a small diameter tube that extends to a sufficient height above ground level to contain the static water level can be attached to the closed casing. The water level inside the small diameter tube above the ground surface is measured. The result will provide the piezometric level (static water level) in metres (ft) above the ground surface. The conversion calculation in step 2 (above) is then used to obtain the artesian head pressure.

Best Management Practice – Determining Pressure Prior to Well Construction

To obtain information about local piezometric head (static water level) conditions in flowing well areas prior to constructing the well, a person constructing a well can, in combination with following the best management practices titled: “Planning to Control the Flow”:

- measure the pressure at a nearby flowing well using a pressure gauge and follow the procedures in method 1 (above) if a nearby flowing well has been constructed with an appropriate control device. As an alternative, the person could follow method 3 (above).
- obtain static water level, aquifer and pressure information for an area from hydrogeological reports.

Figure 12-4: Flowing Well Pressure Gauge Device

Figure 12-5: Flowing Well Pressure Gauge Device - Installed

Figure 12-4 and Figure 12-5 show a flowing well pressure gauge device. It is made with an EPDM rubber packer which is sealed between two stainless steel plates at the bottom of the device. A steel rod with a tightening device and pressure gauge is installed to the packer (Figure 12-4). The packer is installed into the top of the well casing (Figure 12-5). Using the tightening rod, the steel plates squeeze the EPDM rubber to the sides of the well casing which pressurizes the water column. The pressure is detected by the device through the steel rod into the gauge. The gauge provides the artesian head pressure at the elevation of the gauge.

Reminder: Pressure gauge devices should only be used on new and existing wells that will not allow groundwater to flow up and around the well casing.

Downhole hydrostatic head pressure (DHHP)

To determine the pressure at the top of the aquifer, the measured or calculated piezometric level (static water level) in metres (or ft) above the ground surface is added to the measured level of the top of the aquifer encountered in the well in metres (or ft) below the ground surface. For example, if the peizometric level is 10 m above the ground surface and the depth to the top of the aquifer is 40 m below the ground surface, then the total distance between the two measurements is 50 m (i.e., 10 + 40).

To convert the distance measurement to pressure, the following conversions are important:

1 metre equals 10.0 kPa
1 foot equals 0.433 psi

Multiplying the distance in metres (or ft) between the piezometric level (or static water level) to the top of the aquifer by 10 kPa (or 0.433 psi) will provide the downhole hydrostatic head pressure (DHHP) at the top of the aquifer.

Using the above example a distance of 50 m (164ft) multiplied by 10 kPa (or 0.433 psi) results in a DHHP of 500 kPa (or 71 psi).

Downward grout pressure (DGP)

To contain the flow of groundwater going up the well, the downward grout pressure of the material must overcome the downhole hydrostatic head pressure.

In calculating the downward grout pressure (DGP), manufacturers supply fluid densities of mixtures of bentonite and cement in kilograms per litre (kg/L), pounds per American gallon (lbs/US gallon) and, in some cases, pounds per Imperial gallon (lbs/Imp G).

To covert a fluid density to pressure, the multiplication factor of 9.8 can be used for metric units, 0.043 for Imperial units and 0.052 for American units.

Therefore, DGP can be calculated by:

DGP (kPa) = Grout density (kg/L) × 9.8 × depth to top of artesian aquifer (metres) or
DGP (psi) = Grout density (lbs/Imp G) × 0.043 × depth to top of artesian aquifer (ft) or
DGP (psi) = Grout density (lbs/US gallon) × 0.052 × depth to top of artesian aquifer (ft)

Example of how to apply the DGP

In the previous example, the DHHP was calculated to be 500 kPa (or 71 psi). The top of the aquifer is 40 m from the ground surface. The multiplication factor is 9.8.

Therefore to determine if a 40 m column of cement mixed with water to a density of 1.8 kg/L will stop the flow and if a 40 m column of bentonite mixed with water to a density of 1.2 kg/L will stop the flow:

The DGP of cement = 1.8 kg/L × 9.8 × 40 m = 705.6 kPa.

The DGP of bentonite = 1.2 kg/L × 9.8 × 40 m = 470.4 kPa.

Since the DGP of cement is 205.6 kPa greater than the DHHP of the aquifer, the cement will likely stop the flow.

Since the DGP of bentonite is 29.6 kPa less than the DHHP of the aquifer, the bentonite will likely not stop the flow and thus, groundwater will continue to discharge out of the well.

Reminder: See the Tools Section at the end of this chapter for kPa and psi conversions.

Consideration 5: Determineing Well Construction Equipment And Site Specific Design

As with the design of any well, the equipment and methods used should be considered prior to breaking ground (see Chapter 5: Constructing Casing & Covering the Well, for details). When designing a well that is to be installed in an area in which flowing conditions may be encountered, there are additional considerations and equipment that may be required to control the flow.

Well design considerations include:

- Drilling systems:
  - Typical drilling systems that are used:
    - Rotary (mud, air, reverse)
    - Duel rotary
    - Cable tool
  - Systems that are generally not recommended for use when flowing conditions may be encountered:
    - Augering
    - Boring and digging
    - Jetting
    - Driving
- Grouting Materials:
  - The extra density of cement grouts (i.e., they have a higher downward grout pressure) may allow them to overcome the downhole hydrostatic head pressure better than lighter bentonite slurries. Some grouting materials include:
    - Cement based (e.g., neat cement, high-early strength)
    - Neat cement slurry with accelerator (e.g., calcium chloride)
    - Concrete
    - Bentonite slurry
    - Weighting agent (barite) added to bentonite slurry
- Other considerations that affect the design of a flowing well include:
  - Depth
  - Diameter
  - Single casing vs. multiple casing
  - Screened well vs. open bottom
  - Overburden vs. bedrock aquifer formation
  - Naturally developed vs. gravel pack screen
  - Aquifer water quality (e.g., high sulphates may affect certain types of cement grout material and high total dissolved solids may affect bentonite)
  - Use of the well (e.g., municipal, domestic, monitoring, industrial, commercial)
- Approvals:
  - The potential requirement to obtain a Permit to Take Water (PTTW) from the Ministry, or any other approval is an important consideration and should be determined prior to the construction of the well.

Reminder: A Permit to Take Water under the *Ontario Water Resources Act* may be required when the flow of groundwater freely discharges from a well at a rate that is greater than 50,000 L on any one day (11,000 G/day). Therefore, it is important that the person constructing the well estimate the taking before constructing the well. If the estimate shows the flow will take more than 50,000 L on any one day, then the person constructing the well may need to obtain a Permit To Take Water from the Ministry prior to construction. If during construction the person takes more than 50,000 L of water in one day without a permit, the person may be subject to enforcement (e.g., orders and charges). More information on Permits to Take Water can be found on the Ontario website.

Reminder: A sewage works environmental compliance approval under the *Ontario Water Resources Act* may be required if the person discharges the water from the well owner's property and the discharge capacity exceeds 10,000 litres per day. It is important for the person to determine if an environmental compliance approval is required before discharging the well water during the testing of the well yield. A guide to explain the sewage works process can be found on the Ontario website.

Concerns When Encountering Flowing Conditions [3]

The additional considerations including planning, materials, expertise and equipment needed to properly construct a well under flowing conditions, can result in substantial costs not associated with routine well construction. If a flowing well is constructed improperly, the ensuing costs are likely to be even greater, as discussed in this section.

Damage from Flow Breakout may cause the following incidents:

- The uncontrolled discharge of groundwater from flowing wells can cause flooding of the well site and adjacent properties and damage to nearby structures.
- Silt, clay, gravel, sand, and drilling fluids can be carried along with the artesian groundwater to the ground surface and eventually reach surface water. This can alter the quality of the surface water and the habitat of aquatic organisms can be impacted.
- Colder water temperatures from a flowing well discharge can alter the habitat of warm water aquatic species.
- The uncontrolled discharge of groundwater from flowing wells can cause loss of water pressure and water supply to neighbouring wells.
- The uncontrolled discharge of groundwater affects groundwater pressures measured in the flowing hole and the surrounding area. Such conditions may result in underestimation of actual groundwater pressures to be expected at a project site. This can seriously affect the technical feasibility of the project, the construction techniques, the safeguards required and the cost of the project.
- Flow along the outside of the casing can quickly enlarge the hole and form subsurface voids.
- A large volume of geologic material can erupt during a breakout or blowout and create unstable, hazardous conditions at the surface.

Cost of Flowing Conditions

Improper construction, repairs, maintenance and abandonment of a flowing well can be costly.

Unanticipated costs that may arise from flowing conditions include extensive damage to property, restoration of the environment and regulatory enforcement (e.g., orders and fines).

Costs associated with individual flowing wells can be in the tens of thousands of dollars and have exceeded one million dollars in Ontario.

Permits and Other Regulatory Approvals

As indicated previously, flowing wells may require a Permit To Take Water from the Ministry of the Environment and Climate Change if the flow of groundwater is discharging out of the well at more than 50,000 litres on any one day during construction or after construction. Other discharge approvals may be necessary if the groundwater from the flowing well discharges into other waters such as a lake, creek or river. Obtaining these permits and approvals can be expensive and time consuming for both the person constructing the well and the well owner.

Figure 12-6: Creation Of Subsurface Void

Figure 12-6 shows the back of an orange coloured drilling rig. A black coloured drilled well casing extends out of the muddy water through a rotary table. The drilling rig is holding on to the casing with the rotary table and a welded piece of steel. During drilling the flow around the outside of the casing created a void in the ground. The overburden above the void has collapsed creating a 10 metre (30 foot) deep by 4 metre (13 foot) wide hole filled with water. The void was unknown until the time of overburden collapse. The void created a serious safety issue for anyone working on the back of the drilling rig.

Figure 12-7: Creation Of Subsurface Void

Figure 12-7 shows the same drilling rig and void shown in Figure 12-6. The drilling rig is slowly falling into the hole jeopardizing the drilling rig. In this case, the well contractor took immediate measures to fill the void and rescued the drilling rig.

Discharge (Flow) Control [4]

The *Wells Regulation* requires that an appropriate device be installed on a well that becomes a flowing well. The device must control the discharge of water from within the well casing. The well must be constructed and the device must be installed in a way that prevents any uncontrolled flow of water from the well or at the well site. The device must be capable of stopping the discharge from within the well casing, must be capable of withstanding the freezing of water in the well casing, and must be compatible with the well.

Proper control of discharge water from a flowing well consists of:

- controlling, and if necessary, stopping the discharge of water from within the well casing, and
- preventing the discharge of water from around the casing by tightly sealing the juncture between the hole wall and the well casing (annular space) and in some cases between two well casings

A device can consist of one or many components installed in or connected to a well. The following are two examples:

- An air vacuum valve, or a combination air vacuum valve and air release valve, may need to be installed on a flowing well packer (Figures 12-8 to 12-10).
- An in-line ball-valve may need to be installed in the waterline or plumbing when using a multiple drawdown seal (Figure 12-11).

The following sections in this chapter provide examples of devices and methods that are compliant with the *Wells Regulation* and some that are not compliant.

Compliant Devices And Methods

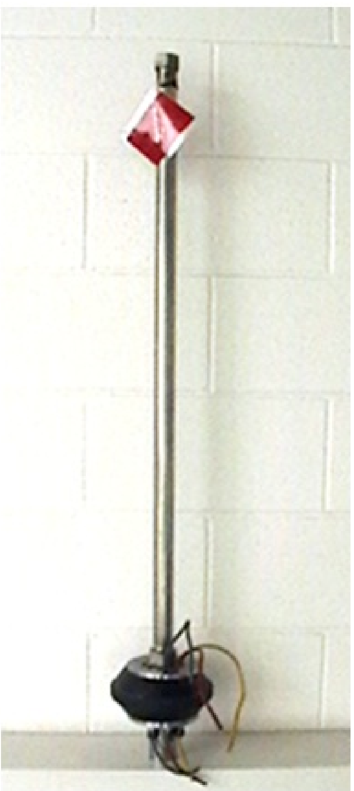
When selecting a flow control device, it is important to consider the environmental conditions (e.g., freezing), well design and water pressure within the well. A device should be assessed to determine if it can withstand the pressure exerted by the water in the well.

There are a variety of devices that can control the flow from within the well casing. The following are examples of flow control devices:

- Flowing well packer (Figure 12-8 to Figure 12-10)
- Drawdown seals (sometimes called flowing well packer) with clamp on pitless adapter (Figure 12-11)
- Flowing well pitless unit, spool type (Figure 12-12)
- Extending the casing above the static water level elevation
- Installing a watertight well cap or welded plate to the top of the well casing

Reminder: Figures 12-8 to 12-12 illustrate some examples of compliant devices and methods which meet the *Wells Regulation* requirements for controlling and, if necessary, stopping the flow of water from within the well casing.

Figure 12-8: Flowing Well Packer



This photograph shows a flowing well packer unit. The unit consists of a packer located at the bottom of a long stainless steel rod. The length of the rod allows the packer to be placed below the frost line. The packer is made out of black coloured EPDM rubber between two stainless steel plates.

The bottom of the packer is equipped with an air vacuum valve or a combined air vacuum and air release valve to ensure that air can move into and out of the well but water cannot.

The photograph shows the packer area comes equipped with proper gauged electrical cables. Electrical wiring from the submersible pump in the well can be attached to the cables in the bottom of the unit. Electrical cables can be attached to the top of the packer to allow the wiring to extend out of the well and connect to the electrical service.

At the top of the steel bar is a nut. A socket wrench can be attached to the nut and can turn the steel bar. When installed in the well, turning the bar squeezes the plates and expands the packer to the sides of the well casing.

The manufacturer should be consulted to ensure the various parts of the unit can withstand the pressure exerted by the water column.

Reminder: See Figures 12-9 and 12-10 for further information on the installation of the flowing well packer.

Reminder: An air vacuum relief valve is designed to allow air to enter into a system and vent air out of a water system rapidly. Once the water encounters the valve, the weighted ball in the valve seals to the plate in the valve creating a watertight seal, an air release valve allows any gas build up in the water column to slowly vent from the water column while maintaining a watertight seal.

Reminder: If a pump is installed in a drilled well, an air vacuum relief valve and, if necessary, a combined air vacuum relief and air release valve must be installed on the drawdown seals to vent the well.

Reminder: Proper safety precautions and warnings should be provided to all persons who will be repairing and servicing wells with these types of devices as the high water pressure can force packers to be pushed out of a flowing well at high velocity.

Figure 12-9: Flowing Well Packer

The flowing well packer shown in Figure 12-9 is being installed in a drilled well that is freely flowing.

At the bottom of the packer is the combined air vacuum valve and air release valve.

The packer is made out of black coloured EPDM rubber between two stainless steel plates. The person installing the device will push the packer into the drilled well using the stainless steel bar.

The red and black electrical wires are also shown extending through watertight seal areas in the packer. Electrical wiring from the submersible pump in the well can be attached to the wires in the bottom of the unit. Electrical wiring can be attached to the top of the unit to allow the wiring to extend out of the well and connect to the electrical service.

The manufacturer should be consulted to ensure the unit can withstand the pressure exerted by the water column.

Figure 12-10: Flowing Well Packer

Figure 12-10 shows the flowing well packer installed in the well. A socket wrench has been used to turn the nut attached to the steel bar. Turning the bar forces the steel plates together, expands the EPDM rubber to the side of the steel casing creating a watertight seal and shuts the flowing water off below the frost level.

Typically, a pitless adapter, drop pipe and pump are installed below the flowing well packer. Electrical wires run from the service to the well, through the top of the well casing and attach to the wiring on the packer. Electrical wires from the submersible pump in the well attach to the electrical wires on the bottom of the packer. A typical vermin proof well cap can be installed on top of the well casing with an air vent and a plug in the electrical conduit.

Figure 12-11: Flow Control Using Drawdown Seals (With Clamp-On Pitless Adapter) [5]

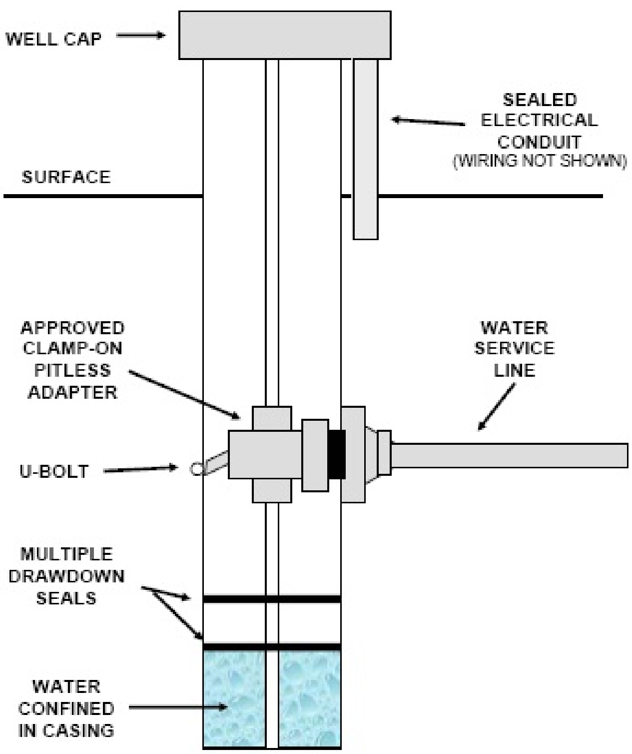


Figure 12-11 is a cross-section diagram of a flow control using draw down seals (with clamp-on pitless adapter).

The diagram shows the upper portion of a well. The well consists of casing that extends vertically from above the ground surface to a distance below the ground surface. A vermin-proof well cap has been placed on top of the casing. The ground surface is shown as being horizontal around the well. On the right side exterior of the casing, an electrical conduit (wiring not shown) extends from the ground surface into the bottom of the vermin-proof well cap. Inside the casing, a hold down pipe extends from the bottom of the vermin-proof well cap, through the approved clamp-on pitless adapter then through multiple draw down seals and into the bottom of the well. An approved clamp-on pitless adapter is attached to the interior of the casing above the multiple drawdown seals. There is a U-bolt at the

left side of the pitless adapter. Confined water is shown inside the casing below the multiple drawdown seals. On the right side of the casing, a horizontal water service line extends from the casing at the approved pitless adapter to the right side of the diagram.

Reminder: The diagram is not to scale, is for illustrative purposes only and does not necessarily represent full compliance with other requirements found in the *Wells Regulation* (e.g., proper mounding).

Reminder: If a pump is installed in a drilled well, an air vacuum relief valve and if necessary, a combined air vacuum relief and air release valve must be installed on the drawdown seals to vent the well.

Reminder: The manufacturer should be consulted to ensure the unit can withstand the pressure exerted by the water column.

Reminder: Drawdown seals (with clamp-on pitless adapters) can be difficult to repair and service. Proper safety precautions and warnings should be provided to all persons who will be repairing and servicing wells with these types of devices as the high water pressure can force the seals to be pushed out of a flowing well at high velocity.

Figure 12-12: Flow Control Using Flowing Well Pitless Unit-Spool Type

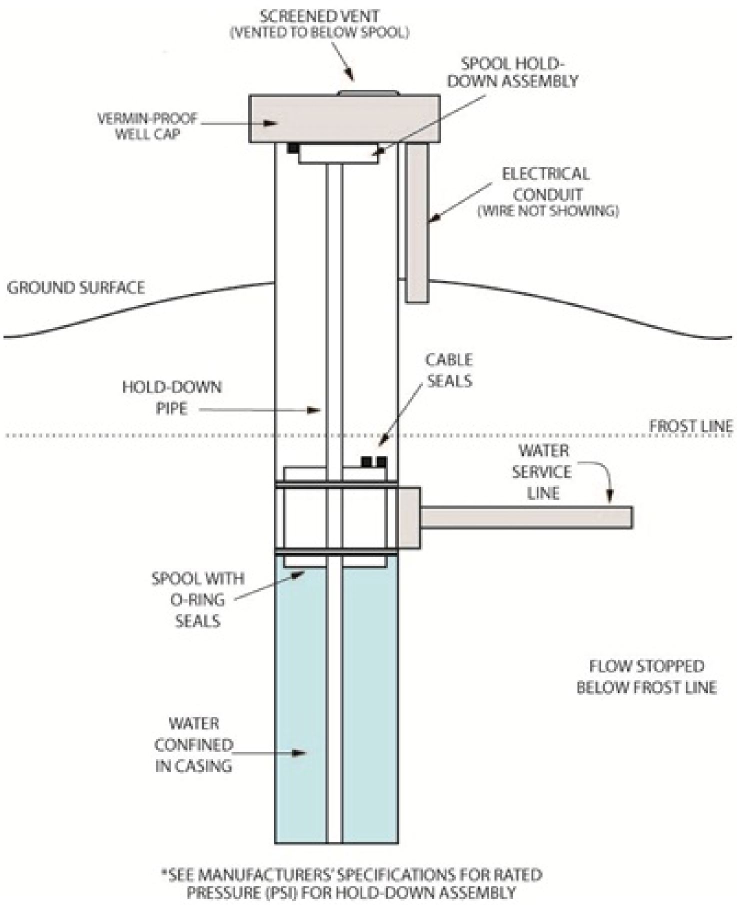


Figure 12-12 is a cross-section diagram of a flow control using a flowing well pitless unit – spool type.

The diagram shows the upper portion of a well. In the upper portion of the subsurface, there is a horizontal dotted line that represents the frost line. The well consists of casing that extends vertically from above the ground surface to a distance below the ground surface. A vermin-proof well cap has been placed on top of the casing. A screened vented (vented to below the spool) is located on top of the vermin-proof well cap. On the right side exterior of the casing, an electrical conduit (wire not shown) extends from the ground surface into the bottom of the vermin-proof well cap. The ground surface is mounded away from the well's casing. Inside the casing, a spool-hold down assembly is attached to the bottom of the vermin-proof well cap. Inside the casing, a hold down pipe extends from the spool-hold down assembly, through the spool and into the bottom of the well. A spool with O-rings is attached to the interior of the casing below the frost line. There are two cable seals on the top of the spool. Confined water is shown inside the casing below the spool. On the right side of the casing, a horizontal water service line extends from the casing at the spool to the right side of the diagram.

There is text on the lower right side of the diagram that states "flow stopped below the frost line". There is text below the bottom of the well that states "see manufacturer's specification for rated pressure (psi) for hold-down assembly.

Pitless units have built-in pitless adapters. The pitless unit shown above has a spool and is typically used for industrial and municipal wells.

A vermin-proof well cap, sealed to the top of the well casing, and a spool holds the assembly below the cap and holds the spool in place.

The spool consists of rubber rings attached to steel plates. The rings and plates seal to the casing above and below a casing connection to the horizontal pipe. The spool confines the water below the frost line in the well casing. The spool also has areas that allow for electrical cables to run to the submersible pump in the well.

Reminder: The diagram is not to scale, for illustrative purposes only and does not necessarily represent full compliance with other requirements found in the *Wells Regulation* (e.g., proper mounding).

Reminder: If a pump is installed in a drilled well, an air vacuum relief valve and, if necessary, a combined air vacuum relief and air release valve must be installed on the system to vent the well.

Reminder: The manufacturer should be consulted to ensure the unit can withstand the pressure exerted by the water column.

Raising The Well Casing, Installing A Watertight Well Cap Or Installing A Welded Cap

In some cases, raising the casing above the static water level elevation or installing a watertight well cap or welded plate on the top of a well casing can stop the flow of water out of the top of the well casing.

In these cases, water above the frost line is prone to freezing in the winter. Casing and caps must be made and installed to withstand cold temperatures and possible freezing.

If a pump is installed in a flowing drilled well, raising the casing or placing a watertight well cap may not be an appropriate device because the well needs to be vented.

Reminder: Watertight well caps and welded plates on wells can be difficult to repair and service. Proper safety precautions and warnings should be provided to all persons who will be repairing and servicing wells with these types of devices as the high water pressure can force the caps or plates to be pushed out of a flowing well at high velocity.

Non-Compliant Devices And Methods

Figures 12-13 to 12-16 illustrate some examples of non-compliant devices and methods that do not control the follow in accordance with the *Wells Regulation*.

Reminder: Figures 12-13 to 12-16 are not to scale and for illustrative purposes the chapter only. The diagrams are only intended to show the non=compliant flow control method/device and not intended to show other aspects of regulatory compliance (e.g., proper mounding).

Figure 12-13: Unapproved Annular Flow - Discharge Piping [6]

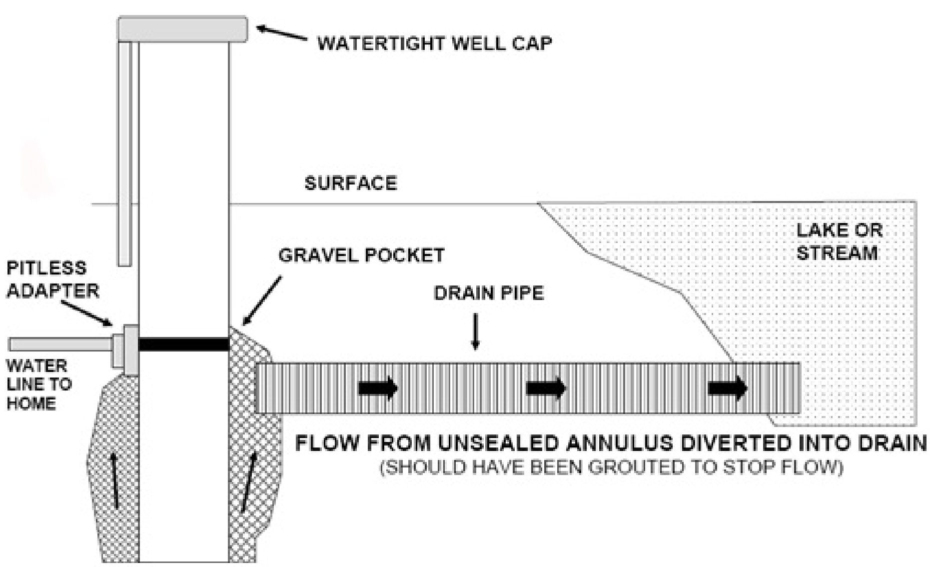


Figure 12-13 is a cross-section diagram of an unapproved annular flow – discharge into a drain, river or stream.

The diagram shows the upper portion of a well. The well consists of casing that extends vertically from above the ground surface to a distance below the ground surface. A watertight well cap has been placed on top of the casing. The ground surface is shown as being

horizontal around the well. A lake or stream is located on the right side of the diagram. On the left side exterior of the casing, an electrical conduit (wire not shown) extends from the ground surface into the bottom of the well cap. On the left side of the casing and below the ground surface, a pitless adapter has been connected to the casing. A horizontal waterline extends from the pitless adapter to the left side of the diagram. There is an annular space around the casing that extends from the pitless adapter to the bottom of the diagram. The annular space has been filled with gravel. On the right side of the well at about the same depth as the horizontal water line, there is a horizontal drain pipe. The horizontal drain pipe extends from the gravel to a lake or stream. There are arrows pointing upward in the gravel that demonstrates how the pressurized groundwater flows up the gravel zone to the horizontal drain pipe. There are arrows in the drain pipe going from the well to the lake or stream that demonstrates how the pressurized groundwater flows from the well to the lake or stream.

There is text below the horizontal drain pipe that states "flow from unsealed annulus diverted to drain (should have been grouted to stop flow)".

Figure 12-14: Unapproved Buried Flow Discharge Piping With Check Valve, Confining Layer Not Sealed [7]

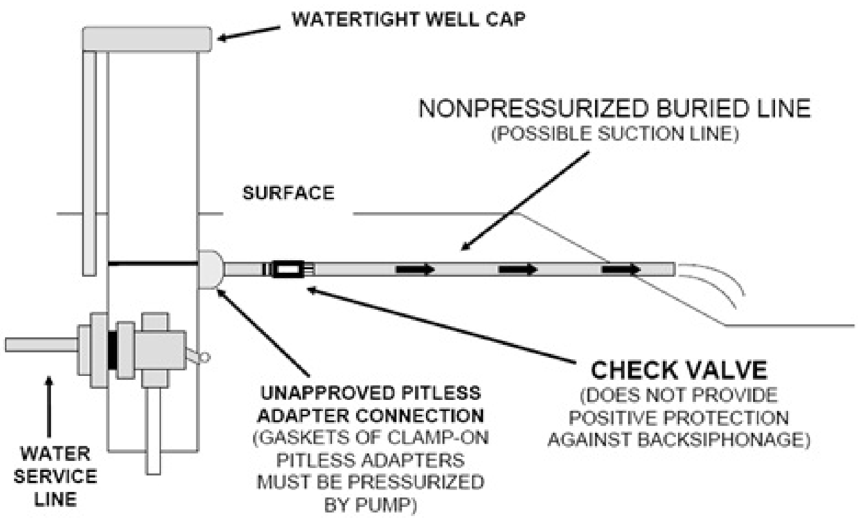


Figure 12-14 is a cross-section diagram of an unapproved buried flow discharge piping with check-valve, confining layer not sealed.

The diagram shows the upper portion of a well. The well consists of casing that extends vertically from above the ground surface to a distance below the ground surface. A watertight well cap has been placed on top of the casing. The ground surface is shown as being horizontal around the well. On the right side of the diagram, the ground surface slopes downward. On the left side exterior of the casing, an electrical conduit (wire not shown) extends from the ground surface into the bottom of the well cap. On the left side of the casing and below the ground surface, a pitless adapter has been connected to the casing. A horizontal water service line extends from the pitless adapter to the left side of the diagram.

On the right side of the well and at a little higher elevation than the horizontal water service line, a clamp-on pitless adapter has been connected to the casing. The clamp-on pitless adapter connection is unapproved because gaskets of clamp-on pitless adapters must be pressurized by a pump. A horizontal non-pressurized buried line (possible suction line) extends from the pitless adapter through the downward sloping ground surface. Near the clamp-on pitless adapter, a check valve has been placed in the horizontal non-pressurized buried line. There is text associated with the check valve that states "does not provide positive protection against back-siphonage).

There are arrows in the horizontal non-pressurized buried line going from the well to the end of the pipe that demonstrates how the pressurized groundwater flows from the well and discharges out onto the ground surface.

Reminder: Figure 12-13 and Figure 12-14 are not to scale and are for illustrative purposes for this chapter only. The diagrams are only intended to show the non-compliant flow control method/device and not intended to show other aspects of regulatory compliance (e.g., proper mounding).

Figure 12-15: Unapproved Control Valve

Figure 12-15 shows that if the valve is shut off, groundwater will overflow the well through the well cap. In this case, water is flowing out of the well even with the valve open.

Figure 12-16: Unapproved Buried Flow Discharge Piping With Submerged Inlet [8]

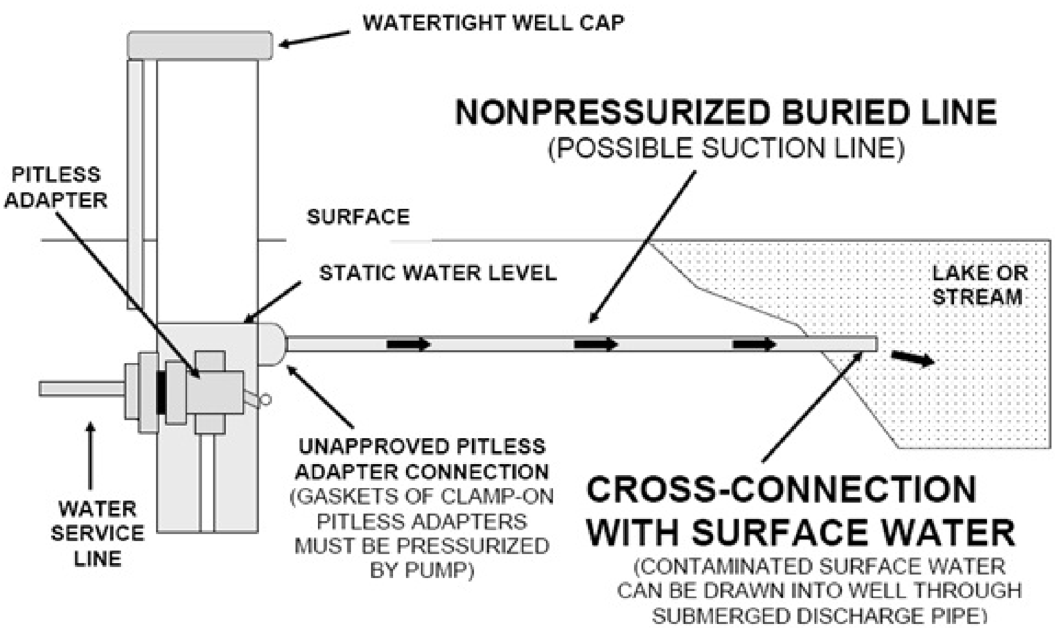


Figure 12-16 is a cross-section diagram of an unapproved buried flow discharge piping with submerged inlet.

The diagram shows the upper portion of a well. The well consists of casing that extends vertically from above the ground surface to a distance below the ground surface. A watertight well cap has been placed on top of the casing. The ground surface is shown as being horizontal around the well. A lake or stream is located on the right side of the diagram. On the left side exterior of the casing, an electrical conduit (wire not shown) extends from the ground surface into the bottom of the well cap. On the left side of the casing and below the ground surface, a pitless adapter has been connected to the casing. A horizontal water service line extends from the pitless adapter to the left side of the diagram.

On the right side of the well and at a little higher elevation than the horizontal water service line, a clamp-on pitless adapter has been connected to the casing. The clamp-on pitless adapter connection is unapproved because gaskets of clamp-on pitless adapters must be pressurized by a pump. A horizontal non-pressurized buried line (possible suction line) extends from the pitless adapter through the downward sloping ground surface.

There are arrows in the horizontal non-pressurized buried line going from the well to the end of the pipe that demonstrates how the pressurized groundwater flows from the well and discharges out to the lake or stream. There is a note associated with the horizontal non-pressurized buried line that states “cross connection with surface water (contaminated surface water can be drawn into well through submerged discharge pipe)”.

Reminder: Figure 12-15 and Figure 12-16 are not to scale and for illustrative purposes only. The diagrams are only intended to show the unapproved flow control method/device and not intended to show other aspects of regulatory compliance (e.g., proper mounding).

Constructing A Well In Flowing Conditions

Before construction begins in a region that is susceptible to flowing conditions, it is essential to have a plan to control the flow of water. The person constructing the well should consider retaining a Professional Geoscientist or Professional Engineer to design the well as suggested in the "Best Management Practice - Planning to Control the Flow" in this chapter. If the person constructing the well is unfamiliar with the area or with flowing well conditions, it is important that a licensed well contractor and well technician (of the correct class) experienced with flowing wells be consulted. In some cases, creating a small diameter pilot hole may be appropriate to determine subsurface conditions.

Flowing Wells Using Common Construction Methods

Some common approaches for well construction when flowing conditions are encountered are described below.

Casing Selection

The selection of casing materials and wall thickness must take into account the water pressures involved and the potential for freezing. For example, plastic is not recommended for use in flowing conditions.

Some forms of casing (e.g., plastic) may be structurally weakened by some types of sealants (e.g., heat of hydration from cement grouts).

Because of the large pressure exerted on the casing, the depth to the artesian flowing aquifer is an important consideration in ensuring the structural integrity of the casing. Knowing the depth of the artesian flowing aquifer will aid in determining the appropriate depth, wall thickness and diameter of the permanent outer casing(s).

Casing Installation

For overburden aquifers, a permanent outer casing should be installed and grouted into the confining layer before an inner well casing is installed through the confining layer into the top of the aquifer.

For bedrock aquifers, a drive shoe should be attached to the bottom of the casing and then seated securely into the bedrock to create a seal.

If a person drills through more than one confining layer and aquifer during well construction, the outer casing, when used, must be sealed into the lowest confining layer prior to advancing an inner casing into the aquifer with flowing artesian conditions.

Constructing an oversized hole compared to casing diameter is also extremely important to ensure an adequate volume of sealant is placed in the annular space to contain the flow of any water.

It is important to take extra care to centre the casing in the oversized hole using devices such as centralizers Centering the casing creates an appropriate annular space around the casing to ensure that proper grout placement can occur along the entire length of the casing.

Long strings of casing should be kept under tension, not compression, during grouting.

Weighting Materials

Drilling and driving a casing into the hole can allow groundwater to escape in an uncontrolled fashion when a flowing well is encountered. Therefore, when dealing with flowing wells, it is common to use drilling fluid (drilling mud) with weighting material to control water while drilling proceeds and ensure that the hole does not collapse prior to casing installation.

Weighting materials such as barite can be used to:

- increase drilling fluid density while maintaining a proper solids/fluid ratio,
- control formation pressure,
- stabilize the hole.

Considerations when selecting a weighting material may include:

- specific gravity,
- quality (e.g., purity),
- degree of corrosiveness and abrasiveness, and
- chemical inertness.

As with grout, the specific gravity of the drilling fluid with weighting material must overcome the downhole hydrostatic head pressure (see "Phase II – Designing a Flowing Well, Consideration 4: Determining Depth, Pressure and Flow of Aquifer" section).

Reminder: It is important to follow the manufacturer's recommended specifications when using drilling fluid with weighting materials. Manufacturers will have tables and guidelines to assist in obtaining the correct drilling fluid density (see Figure 12-17).

Figure 12-17: Densities Of Common Fluids Used In Well Construction [9]

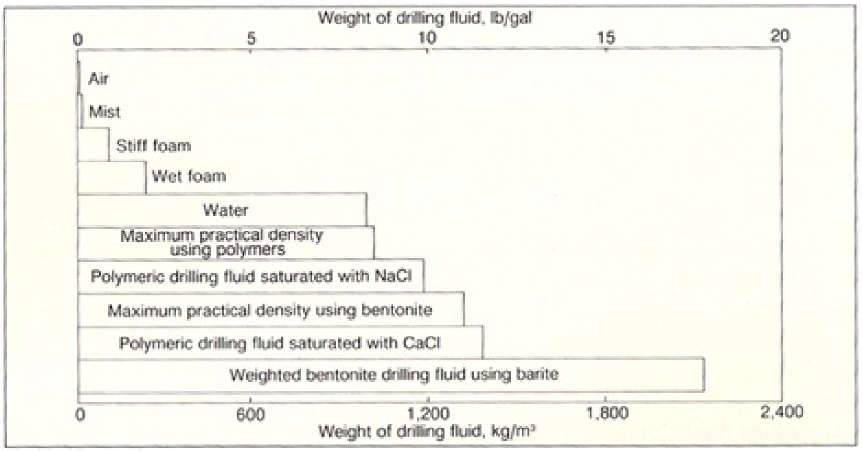


Figure 12-17 is a chart showing densities of common fluids in well construction.

The chart consists of two horizontal lines showing density values in standard and metric units. The upper horizontal line shows weight of drilling fluid in pounds per U.S. gallon (standard units). The standard unit horizontal line is marked in increments of 5, starting at zero and ending at 20. The lower horizontal line shows weight of drilling fluid in kilograms per cubic metre (metric units). The metric unit horizontal line is marked in increments of 600, starting at zero and ending at 2,400.

Between the horizontal rectangles between the horizontal lines that represent ten types of materials. The type of material and its density are shown in the diagram as follows:

- Air – less than 1 pounds per U.S. gallon or less than 1 kilogram per cubic metre
- Mist – about 1 pounds per U.S. gallon or less than 10 kilograms per cubic metre
- Stiff foam – about 1.5 pounds per U.S. gallon or less than 100 kilograms per cubic metre
- Wet foam - about 2 pounds per U.S. gallon or about 100 kilograms per cubic metre
- Water - about 7 pounds per U.S. gallon or about 1,000 kilograms per cubic metre
- Maximum Practical Density using Polymers - about 7.5 pounds per U.S. gallon or about 1,100 kilograms per cubic metre
- Polymeric drilling fluid saturated with sodium chloride - about 10 pounds per U.S. gallon or about 1,200 kilograms per cubic metre
- Maximum Practical Density using Bentonite - about 11 pounds per U.S. gallon or about 1,300 kilograms per cubic metre
- Polymeric drilling fluid saturated with calcium chloride - about 12 pounds per U.S. gallon or about 1,300 kilograms per cubic metre
- Weighted bentonite drilling fluid using barite - about 17 pounds per U.S. gallon or about 2,000 kilograms per cubic metre

  Practical drilling fluid densities range from virtually zero for air, to greater than 1,800 kg/m^3 (15 lb/gal) for bentonite with barite additives. In general, the density of the drilling fluid must be high enough to balance any confined pressure conditions in the hole. Excessive drilling fluid densities, on the other hand, cause high fluid losses, plugging of the aquifer, unsatisfactory cuttings removal in the mud pit and higher-than-necessary pumping costs.[11]

Grouting

Grout (suitable sealant) must be properly placed in the annular space to prevent flowing water problems.

In addition to the methods and considerations described in Chapter 6: Annular Space & Sealing, the rate of flow and water pressures must be considered when selecting a grouting method for a flowing well (see Tables 12-2 to 12-4 in the "Tools" section of this chapter).

The selection of grouting material and required specific density were previously described in the "Phase II – Designing a Flowing Well, Consideration 5: Determining Well Construction Equipment and Site-Specific Design section.

Cement based grouts must properly set (or cure) to the manufacturer's specifications or 12 hours (whichever is longer).

Cement slurries with accelerators such as calcium chloride can allow for quicker set times to prevent dilution, washouts and voids (subsurface erosion) around the casing.

Knowledge of how grouts cure (or hydrate), and experience with mixing and placement of grout is important to ensure that the selected sealant (grout) will perform adequately to contain the flow of water.

When grouting a flowing well, extra materials [e.g., cement, calcium chloride (accelerator), fresh water for mixing, extra tremie lines and fittings, weighting agent (e.g., barite and gel products)] should be on hand and ready for use.

In some cases, the well may be pumped to lower the water level in the hole to allow the placement of a filter pack and the installation of grout.

Flowing Wells Using Other Construction Methods

The use of construction methods such as boring, digging, augering, jetting and driving are generally not recommended where flowing conditions may be encountered. These methods typically pose greater risks and may require additional or different precautions to contain the flow.

Dug, Bored Or Driven-Point Wells

The vast majority of dug, bored and driven point wells are relatively shallow and are located in unconfined aquifers, resulting in a lower likelihood of encountering flowing conditions; however, flowing well conditions can still be encountered during shallow well construction (e.g., near surface water bodies). It is important to take into consideration the indicators of flowing conditions (see “Phase 1- Predicting a Flowing Well section in this chapter) even when constructing these types of wells.

Auger Construction

Auger methods, such as hollow stem or continuous flight augering, are not recommended if flowing conditions are expected. Augering construction presents serious complications if flowing conditions are encountered since casing and weighting materials are not installed during the augering process. Extra caution should be taken when using augering equipment before breaking through a confining formation and into the aquifer. If caution is not taken and flowing conditions are encountered, it will be difficult to install and seal any type of casing into the confining formation to control the groundwater from the flowing well.

Best Management Practice – Seek Second Party Advice

If the person constructing the well has limited experience with flowing well conditions and there is any possibility of an occurrence of a flowing well while using any of the above construction methods, a Professional Engineer, Professional Geoscientist or experienced licensed well technician working for a licensed well contractor should be called to obtain expert advice before starting. The person should also use this Best Management Practice in combination with the “Best Management Practice - Planning to Control the Flow”.

Some Successful Construction Methods

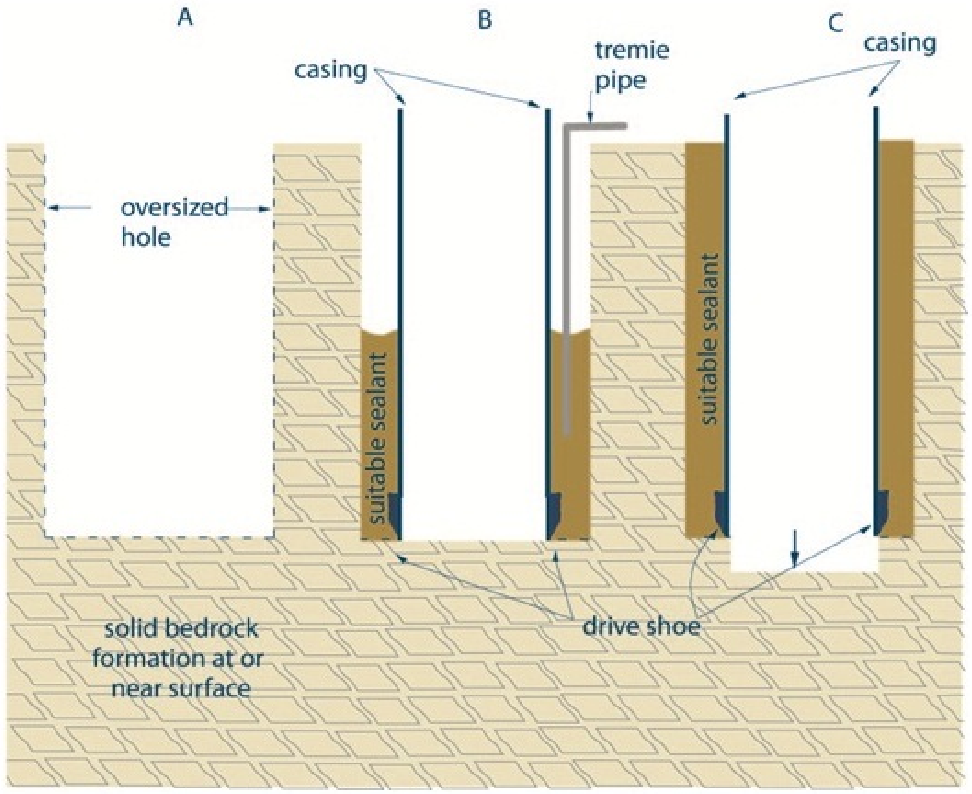
Figures 12-18 to 12-22 illustrate some methods that have been used successfully in the past when encountering flowing conditions. However, it is important that the design for each flowing well be based on site-specific conditions. See the “Phase II – Designing a Flowing Well section of this chapter for details regarding construction considerations when flowing conditions are encountered.

Reminder: The following figures are not to scale, are for illustrative purposes for this chapter only and diagrams do not necessarily represent full compliance with other requirements found in the *Wells Regulation* (e.g., proper mounding). See Chapter 6: Annular Space & Sealing for further details.

Confined Aquifer In Bedrock Where Flowing Conditions Are Expected (Figures 12-18 to 12-20)

If the confined aquifer is located in solid bedrock and the bedrock is at or near the ground surface, the drill hole should be significantly oversized and larger than the outer diameter of the casing. The annular space must be sealed to contain (i.e., stop the movement of) any flowing water in the annular space. This can be accomplished by using a neat cement placed in the annular space and allowing it to cure to the manufacturer’s specifications.

Figure 12-18: Confined Bedrock Aquifer



Construction method for Figure 12-18 can be cable tool, rotary air or down-the-hole hammer.

Step A: Initial hole near the top of the flowing aquifer and diameter is significantly oversized compared to the finished diameter of the casing, to a depth of at least 6 m (20ft). A greater depth may be required to encounter competent rock or to ensure containment.

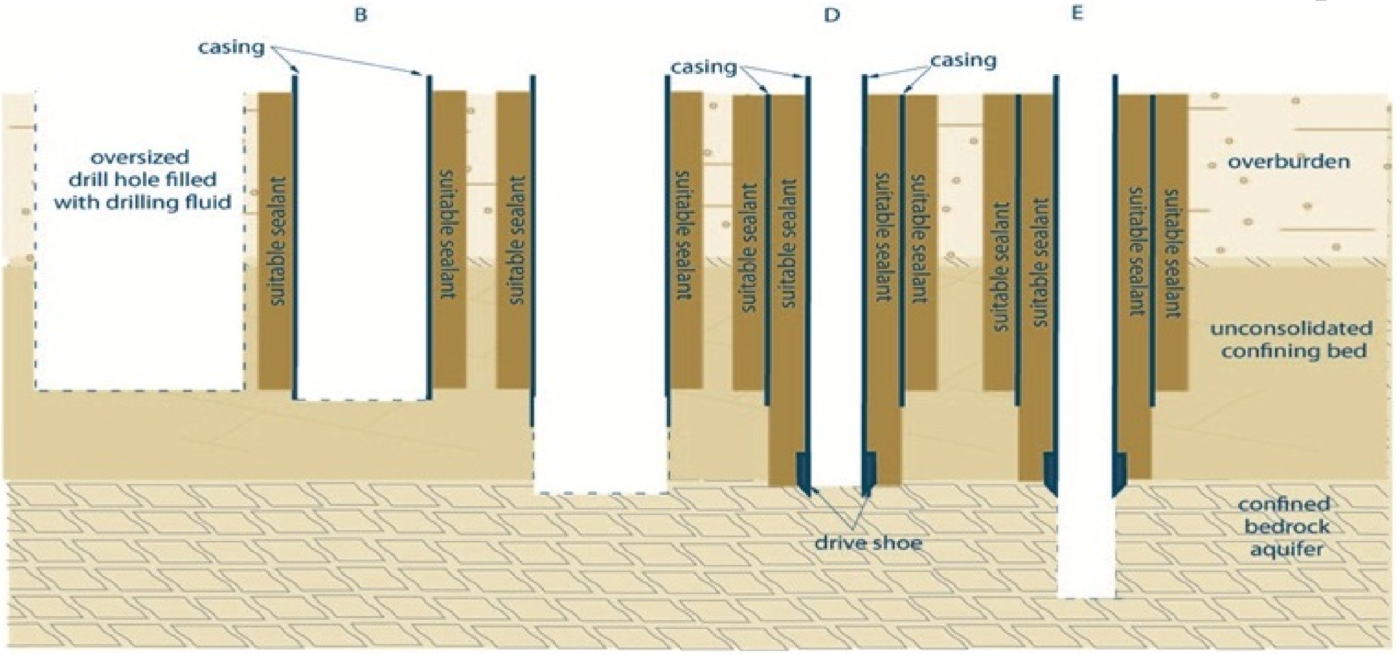
Step B: A smaller diameter casing is installed and centred in the oversized hole.The annular space is filled with a suitable grout/sealant that can withstand the downhole hydrostatic head pressure of the aquifer (for details on sealing the annular space see Chapter 6: Annular Space & Sealing).

Step C: The hole is drilled out the bottom of the inner casing to the flowing artesian aquifer.

Step D: A compatible flow control device is installed on the well [see “Discharge (Flow) Control,”].

Reminder: The figure above is not to scale, it is for illustrative purposes for this chapter only and does not necessarily represent full compliance with other requirements found in the *Wells Regulation* (e.g., proper mounding).

Figure 12-19: Bedrock Aquifer With Confining Overburden Layer - Multiple Casings And Weighted Materials



Construction method for Figure 12-19 can be rotary with drilling mud

Step A: A significantly oversized hole is drilled with weighted drilling fluids (mud) into the confining overburden formation to a depth that is near the top of the confined aquifer.
Note: the hole is oversized compared to the outer casing.

Step B: The outer casing is centred and set to bottom of oversized hole.
The annular space is filled with a suitable grout/sealant that can withstand the downhole hydrostatic head pressure of the aquifer.

Step C: The hole is drilled out through the bottom end of the casing into the top of the aquifer using weighted drilling fluids (mud).
The hole diameter is similar to inner diameter of outer casing.

Step D: The inner casing is set to the top of the aquifer and sealed in place with suitable sealant as described in Step B.

Step E: After following recommendations to allow grout to set, drilling can continue into the flowing artesian aquifer.

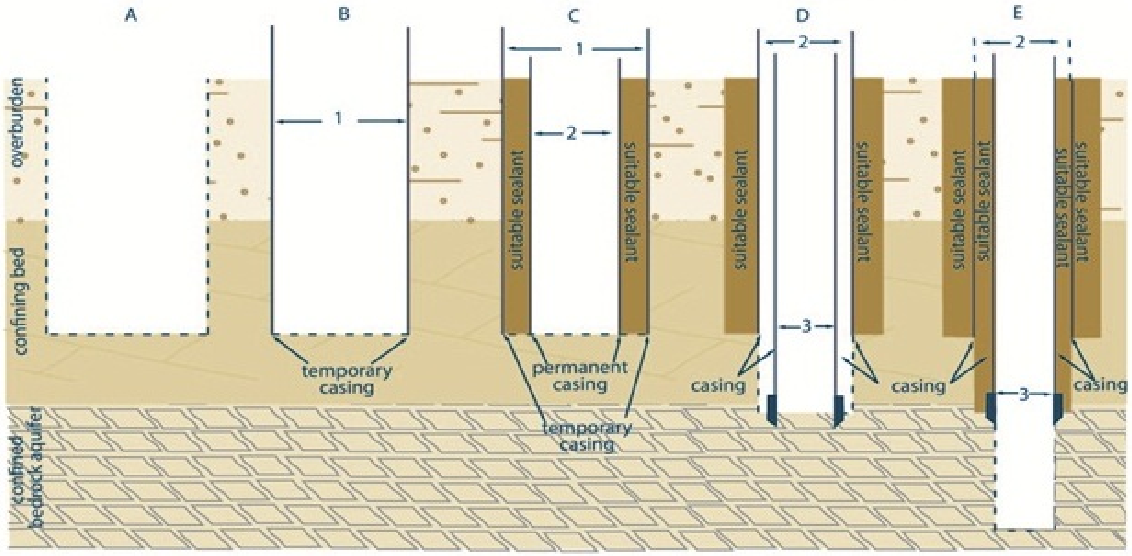
Step F: A compatible flow control device is installed on the well [see "Discharge (Flow) Control,"].

Reminder: The figure above is not to scale, it is for illustrative purposes for this chapter only and does not necessarily represent full compliance with other requirements found in the *Wells Regulation* (e.g., proper mounding).

Reminder: When the confined aquifer is located within consolidated material (bedrock), the inner casing should be driven or a smaller diameter hole drilled and the inner casing set firmly into the bedrock.

Reminder: The annular space around the entire inner casing must be filled from the bedrock to ground surface with suitable sealant. The sealant must be able to withstand the aquifer's downhole hydrostatic head pressure.

Figure 12-20: Bedrock Aquifer With Confining Overburden Layer-Multiple Casings And Temporary Casing



Construction method for Figure 12-20 can be cable tool, rotary air and dual rotary.

Step A: significantly oversized hole is drilled(1).

Step B: The temporary outer casing (2) is advanced into the confining overburden formation to a depth that is near the top of the confined aquifer.
The casing is usually installed at the same time as drilling if formation is susceptible to collapsing.

Step C: The permanent outer casing is centred and set to bottom of oversized hole.
The annular space between temporary and permanent casings is filled with a suitable grout/sealant that can withstand the downhole hydrostatic head pressure of the aquifer.
The temporary casing (1) is removed.

Step D: The hole is drilled out through the bottom of the casing (2). The hole diameter similar to the inner diameter of the outer casing(2).
Weighted drilling fluids (mud) may be used to contain the flow.
An inner casing(3) is installed to the bottom of the hole seated into bedrock and sealed into bedrock and sealed in place with suitable sealant as described in C.

Step E: The annular space between inner(3) and outer(2) permanent casings is filled with a suitable grout/sealant that can withstand the downhole hydrostatic head pressure of the aquifer.
After following recommendations to allow grout to set, drilling can continue into the bedrock to the flowing artesian aquifer.

Step F: Compatible flow control device is installed on the well [see Discharge (Flow)].
At least one casing must stick up at least 40cm (16 inches) above the highest point on the ground surface within 3 m(10 ft) radially from the outside of the well casing.

Reminder: The diagram above is not to scale, it is for illustrative purposes for this chapter only and does not necessarily represent full compliance with other requirements found in the *Wells Regulation* (e.g., proper mounding).

Reminder: When the confined aquifer is located within consolidated material (bedrock), the inner casing should be driven or a smaller diameter hole drilled and the casing set firmly into the bedrock.

Reminder: The annular space around the entire inner casing must be filled from the bedrock to ground surface with suitable sealant. The sealant must be able to withstand the aquifer's downhole hydrostatic head pressure.

Confined Aquifers In Overburden Where Flowing Conditions Are Expected (Figures 12-21 To 12-22)

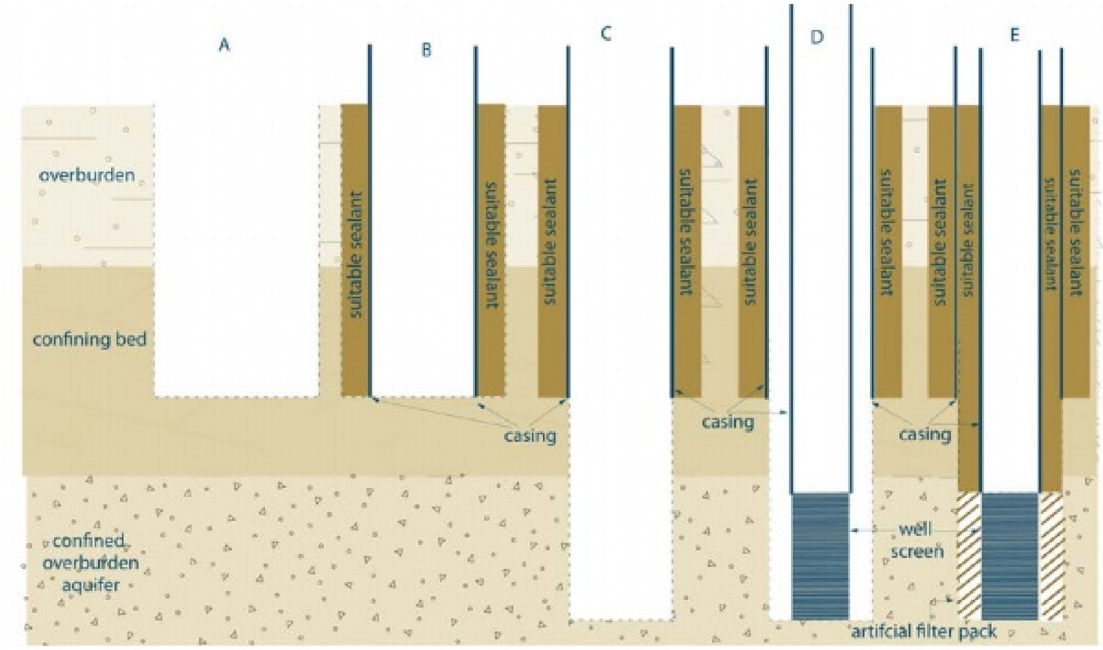
The well should be double cased as a minimum and the annular space should be pressure grouted.

Another method that may be used to control flowing conditions is to set a permanent outer casing, install a packer at the bottom of the casing, install the inner casing, and pressure grout through the packer between the two casings.

The outer casing should be adequately sealed into the impermeable layer so as to prevent surface and subsurface leakage from the artesian aquifer.

It is important not to extend (i.e., drill) too far into these types of overburden aquifers as high water pressures can cause piping (subsurface erosion), wash outs and crevasses to form around the casing during drilling.

Figure 12-21: Overburden Aquifer With Confining Layer - Multiple Casing And Weighted Materials



Construction method for Figure 12-21 can be rotary with drilling mud.

Step A: A significantly oversized hole is drilled with weighted drilling fluids (mud) into the confining overburden formation to a depth that is near the top of the confined aquifer.
Note: the hole is oversized compared to the outer casing.

Step B: The outer casing is centred and set to bottom of oversized hole. The annular space is filled with a suitable grout/sealant that can withstand the downhole hydrostatic head pressure of the aquifer.

Step C: The hole is drilled out through the bottom of the casing into the top of the flowing aquifer using weighted drilling fluids (mud). The hole diameter is similar to inner diameter of outer casing.

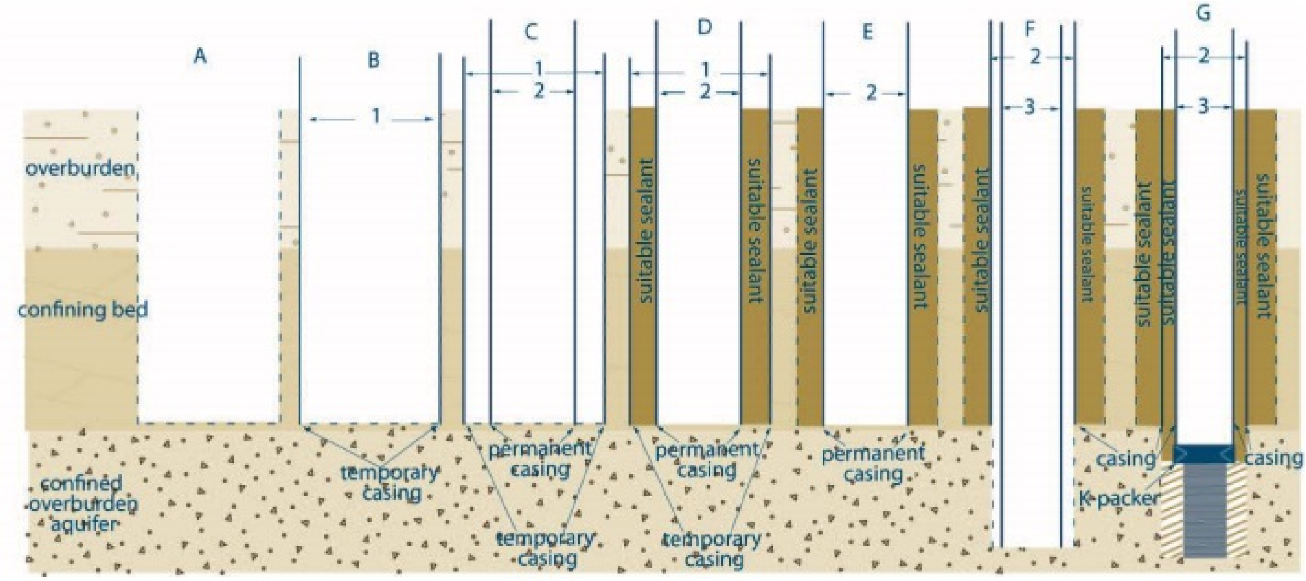
Step D: The inner casing and well screen are centred and set into aquifer with weighted mud.

Step E: The artificial filter pack is placed around well screen.
The annular space from the top of the filter pack, including between permanent casings, is filled with a suitable grout/sealant that can withstand the downhole hydrostatic head pressure of the aquifer.

Step F: A compatible flow control device is installed on the well [see "Discharge (Flow) Control,"].
At least one casing must stick up at least 40 cm (16 inches) above the highest point on the ground surface within 3 m (10ft) radially from the outside of the well casing.

Reminder: The diagram above is not to scale, it is for illustrative purposes for this chapter only and does not necessarily represent full compliance with other requirements found in the *Wells Regulation* (e.g,, proper mounding).

Figure 12-22: Overburden Aquifer With Confining Layer - Multiple Casings And Temporary Casing



Construction method for Figure 12-22 can be cable tool, rotary air and dual rotary.

Step A: A significantly oversized hole is drilled into the confining overburden formation to a depth that is near the top of the confined aquifer.

Step B: A temporary outer casing (1) is advanced into the confining overburden formation to a depth that is near the top of the confined aquifer.
Note: the hole is oversized compared to the permanent outer casing

Step C: The permanent outer casing (2) is centred and set to bottom of temporary casing.

Step D: The annular space between temporary (1) and permanent (2) casings is filled with a suitable grout/sealant that can withstand the downhole hydrostatic head pressure of the aquifer.

Step E: The temporary casing (1) is removed

Step F: The hole is drilled out through the bottom of the casing (2) while advancing an inner casing (3) into the top of the aquifer. The hole diameter is similar to the inner diameter of the permanent outer casing.
Weighted drilling fluids (mud) may be used to contain the flow.

Step G: A telescopic well screen is installed at the bottom of casing and the casing is pulled back to expose the well screen to the formation.
The annular space between inner and outer permanent casings is filled with a suitable grout/sealant that can withstand the downhole hydrostatic head pressure of the aquifer.

Step H: A compatible flow control device is installed on the well [see Discharge (Flow) Control].
At least one casing must stick up at least 40 cm (16 inches) above highest point on the ground surface within 3 m (10ft) radially from the outside of the well casing.

Reminder: The diagram above is not to scale, it is for illustrative purposes for this chapter only and does not necessarily represent full compliance with other requirements found in the *Wells Regulation* (e.g., proper mounding)

Well Contractor Responsible For Costs

The *Wells Regulation* - If a well becomes a flowing well during well construction (including installing a pump and any alterations), the well contractor is responsible for the cost of complying with the flowing well construction or abandonment requirements in the *Wells Regulation* (see Plainly Stated section of this chapter).

This includes the following actions and any costs associated with them:

- The proper construction of the well that prevents any uncontrolled flow from the well (which includes the area around the well casing) or at the well site and the installation of an appropriate device in or on the well that:
    - controls the discharge of water from within the well casing,
    - is capable of stopping the flow of water from within the well casing,

- is capable of withstanding the freezing of water in the well casing, and
- prevents the backflow of water into the well, or
- The abandonment of the well in accordance with the *Wells Regulation* requirements (see Chapter 15: Abandonment: How to Plug & Seal Wells).

The *Wells Regulation* - Every contract between the well purchaser and the well contractor for the construction of a well is deemed to contain a term that makes the well contractor responsible for the costs of:

- complying with the above requirements and
- abandoning the well, if applicable.

Reminder: This is the case irrespective of whether the contract is written or verbal or whether this responsibility is explicitly written into the contract or not. The only exception is if there is a written contract between the well contractor and well purchaser that specifically releases the well contractor from these costs.

Reminder: Even if the well contractor is relieved from the costs, the person constructing the well must still meet the *Wells Regulation* requirements to control or abandon the flowing well, as stated in the Plainly Stated section of this chapter.

Encountering A Flowing Well Unexpectedly

When constructing a well including deepening of an existing well, installation of a pump or another alteration, it is possible that a flowing well situation may be unexpectedly encountered. This is a situation that can become seriously problematic very quickly. It is important to always be prepared and know:

1. How to control and stop an unexpected flowing well as explained in this chapter.
2. How to abandon an unexpected flowing well as explained in Chapter 15: Abandonment: How to Plug & Seal Wells.

Consulting A Professional

Best Management Practice – Consulting a Professional

The person constructing the well should immediately retain a Professional Geoscientist or Professional Engineer (consultant) experienced in hydrogeology and flowing well conditions, to assess the unexpected flowing well and the hydrogeology around the flowing well.

After the consultant has assessed the flowing well and the hydrogeology around the well, the consultant should provide the person constructing the well with recommendation(s) to either abandon the well or to properly construct the well and install an appropriate device to control, and if necessary, shut off the flow of water from the well.

The person constructing the well should immediately implement the consultant's recommendations to prevent any adverse effects such as flooding. As a suggestion, the person constructing the well could have the consultant observe the rectification operation at the flowing well to ensure the recommendations are followed.

Installing Pumps In Existing Flowing Wells Or Where A Well Becomes A Flowing Well After It Has Been Constructed

There are many health and safety concerns when working on existing flowing wells with control devices. The high pressures in the water column can cause devices, such as packers and portions of the adapters, to be pushed out of a flowing well at high velocities. There have been cases where people have been seriously injured trying to remove control devices.

The removal of devices has also resulted in flooding problems, the discharge of contaminated well water into surface water and flows exceeding 50,000 litres per day without a Permit To Take Water from the Ministry.

It is important that proper safety and environmental precautions (including obtaining any environmental approvals such as a (see Permits and Other Regulatory Approvals section in this chapter) be observed by anyone who will be repairing and servicing wells with these types of devices to avoid injury and protect the environment.

There are also many concerns when working on existing flowing wells that do not have control devices. See the "Concerns when Encountering Flowing Conditions" section in this chapter for some of the legal liabilities.

Best Management Practice – Consulting a Professional for Existing Flowing Wells

Prior to working on an existing flowing well or if the well suddenly becomes a flowing well, consider retaining a Professional Geoscientist or Professional Engineer (consultant) experienced in hydrogeology and flowing well conditions to assess the flowing well and the hydrogeology around the flowing well.

After the consultant has assessed the flowing well and the hydrogeology around the well, the consultant should provide the person constructing the well or well owner with recommendation(s) to:

- properly upgrade the well,
- abandon the well and construct a new well, or
- install an appropriate flow control device.

The consultant's recommendations should be implemented. If a person constructing the well is unfamiliar with the area or with repairing flowing wells, it is important that a licensed well contractor and well technician (of the correct class) experienced with flowing wells be consulted and if necessary, retained to do the work.

Tools

Legend for Tables 12-2 and 12-3: Grouting Material Suitability Using Common Neat Cement and Bentonite Products

Symbol	Heavy Enough to Overcome Hydrostatic Pressure	Not Heavy Enough to Overcome Hydrostatic
*	Neat cement grout with a density of 1.8 kg/L with weight additives	Bentonite grout with a density of 1.14 kg/L Bentonite grout with a density of 1.25 kg/L
**	Neat cement grout with a density of 1.8 kg/L	Bentonite grout with a density of 1.14 kg/L
†	Bentonite grout with a density of 1.25 kg/L Neat cement grout with a density of 1.8 kg/L	Bentonite grout with a density of 1.14 kg/L
††	Bentonite grout with a density of 1.14 kg/L	N/A

Reminder: Use this legend in conjunction with Tables 12-2 and 12-3.

Reminder: Example of use of Legend for Tables 12-2 and 12-3 (shown above): Where the top of the aquifer is 3 metres below the ground surface and the piezometric level is 1 metre above the ground surface, the corresponding pressure is calculated to be 39 kPa. The light grey colour indicates a column of 3 metres (distance from ground surface to aquifer in well) of neat cement grout with a fluid density of at least 1.8 kg/L or neat cement grout with weight additives will overcome the aquifer's downhole hydrostatic head pressure of 39 kPa. However none of the common bentonite grouts listed will overcome the downhole hydrostatic head pressure. The listed bentonite grouts will not stop the flow of groundwater out of the well.

Reminder: The tables provide for common grouting products used in the industry to overcome flowing well conditions. It is important that persons trying to overcome flowing wells verify and calculate the density of the grouting mixture before using these tables.

Reminder: After mixing the material at the site, fluid density can be verified in the field using a mud balance.

Table 12-2: Downhole Hydrostatic Head Pressure (kPa) For Flowing Artesian Wells And Common Grouting Materials Used To Overcome The Pressure - Depths Provided In Metres [10]

Depth to top of flowing aquifer from ground surface in metres.	Pressure from grout in kPa with Density of 1.8 kg/L	Pressure from grout in kPa with Density of 1.25 kg/L	Pressure from grout in kPa with Density of 1.14 kg/L	Downhole hydrostatic pressure in kPa for various piezometric levels above ground surface measured at 1 m	Downhole hydrostatic pressure in kPa for various piezometric levels above ground surface measured at 2 m	Downhole hydrostatic pressure in kPa for various piezometric levels above ground surface measured at 4 m	Downhole hydrostatic pressure in kPa for various piezometric levels above ground surface measured at 6 m	Downhole hydrostatic pressure in kPa for various piezometric levels above ground surface measured at 8 m	Downhole hydrostatic pressure in kPa for various piezometric levels above ground surface measured at 10 m
3	53*	37**	34†	39**	49**	69*	88*	108*	127*

Depth to top of flowing aquifer from ground surface in metres.	Pressure from grout in kPa with Density of 1.8 kg/L	Pressure from grout in kPa with Density of 1.25 kg/L	Pressure from grout in kPa with Density of 1.14 kg/L	Downhole hydrostatic pressure in kPa for various piezometric levels above ground surface measured at 1 m	Downhole hydrostatic pressure in kPa for various piezometric levels above ground surface measured at 2 m	Downhole hydrostatic pressure in kPa for various piezometric levels above ground surface measured at 4 m	Downhole hydrostatic pressure in kPa for various piezometric levels above ground surface measured at 6 m	Downhole hydrostatic pressure in kPa for various piezometric levels above ground surface measured at 8 m	Downhole hydrostatic pressure in kPa for various piezometric levels above ground surface measured at 10 m
6	106*	74**	67†	69†	78**	98**	118*	137*	157*
10	176*	123**	112†	108††	118†	137**	157**	176*	196*
15	265*	184**	168†	157††	167††	186**	206**	225**	245**
20	353*	245**	223†	206††	216††	235†	255**	274**	294**
25	441*	306**	279†	255††	265††	284†	304†	323**	343**
30	529*	368**	335†	304††	314††	333††	353†	372**	392**
35	617*	429**	391†	355††	365††	382††	402†	421†	441**
40	706*	490**	447†	402††	412††	431††	451†	470†	490**
50	882*	613**	559†	500††	510††	529††	549††	568†	588†
60	1058*	735**	670†	598††	608††	627††	647††	666††	686†
70	1235*	858**	782†	696††	706††	725††	745††	764††	784†
80	1411*	980**	894†	794††	804††	823††	843††	862††	882††

This table has been prepared using the conversion factor: 1 m = 9.8 kPa

Table 12-3: Downhole Hydrostatic Head Pressure (PSI) For Flowing Artesian Wells And Common Grouting Materials Used To Overcome The Pressure - Depths Provided In Feet [11]

Depth to top of flowing aquifer from ground surface in feet.	Pressure from grout in psi with Density of 15 lbs/US gal or 18 lbs/Imp Gal	Pressure from grout in psi with Density of 10.4 lbs/US gal or 12.5 lbs/Imp Gal	Pressure from grout in psi with Density of 9.5 lbs/US gal or 11.4 lbs/Imp Gal	Downhole hydrostatic head pressure in psi for various piezometric levels above ground surface measured at 5 ft	Downhole hydrostatic head pressure in psi for various piezometric levels above ground surface measured at 10 ft	Downhole hydrostatic head pressure in psi for various piezometric levels above ground surface measured at 15 ft	Downhole hydrostatic head pressure in psi for various piezometric levels above ground surface measured at 20 ft	Downhole hydrostatic head pressure in psi for various piezometric levels above ground surface measured at 25 ft	Downhole hydrostatic head pressure in psi for various piezometric levels above ground surface measured at 30 ft
10	8*	5**	5†	6**	9*	11*	13*	15*	17*
20	16*	11**	10†	11**	13**	15**	17*	19*	22*
30	23*	16**	15†	15†	17**	19**	22**	24*	26*
40	31*	22**	20†	19††	22**	24**	26**	28**	30**
50	39*	27**	25†	24††	26†	28**	30**	32**	35**
75	59*	41**	37†	35††	37†	39†	41**	43**	45**
100	78*	54**	49†	45††	48††	50†	52†	54**	56**
125	98*	68**	62†	56††	58††	61††	63†	65†	67†
150	117*	81**	74†	67††	69††	71††	74†	76†	78†

Depth to top of flowing aquifer from ground surface in feet.	Pressure from grout in psi with Density of 15 lbs/US gal or 18 lbs/Imp Gal	Pressure from grout in psi with Density of 10.4 lbs/US gal or 12.5 lbs/Imp Gal	Pressure from grout in psi with Density of 9.5 lbs/US gal or 11.4 lbs/Imp Gal	Downhole hydrostatic head pressure in psi for various piezometric levels above ground surface measured at 5 ft	Downhole hydrostatic head pressure in psi for various piezometric levels above ground surface measured at 10 ft	Downhole hydrostatic head pressure in psi for various piezometric levels above ground surface measured at 15 ft	Downhole hydrostatic head pressure in psi for various piezometric levels above ground surface measured at 20 ft	Downhole hydrostatic head pressure in psi for various piezometric levels above ground surface measured at 25 ft	Downhole hydrostatic head pressure in psi for various piezometric levels above ground surface measured at 30 ft
175	137*	95**	86†	78††	80††	82††	84††	87†	89†
200	156*	108**	99†	89††	91††	93††	95††	97††	100†
225	176*	122**	111†	100††	102††	104††	106††	108††	110††
250	195*	135**	124†	110††	113††	115††	117††	119††	121††

Reminder: This table has been prepared using the conversion factor: 1 ft = 0.433 psi

Reminder: In Tables 12-2 and 12-3 the top of the aquifer is added to the piezometric level above the ground surface. If the measurement is in metres, then the total measurement is multiplied by 10 to give the pressure in kPa. If the measurement is in ft, then the total measurement is multiplied by 0.433 to give the pressure in psi. For example, where the top of the aquifer is 3 m and the piezometric level is 1.5 m, then the total measurement is 4.5 m × 10 converts to 45 kPa.

Table 12-4: Common Grouting Materials vs. Weight (Fluid Density) vs. Hydrostatic Pressure

Material	Density	Hydrostatic Pressure in kPa (or psi) per metre (or per foot)
Neat Cement at 23 L (6 US gal) water/sack:	1.80 kg/L	17.64 kPa/m
Neat Cement at 23 L (6 US gal) water/sack:	18.0 lbs/gal	0.78 psi/ft
Neat Cement at 23 L (6 US gal) water/sack:	15.0 lb/US gal	0.78psi/ft
Bentonite Slurry Grout:	1.25 kg/L	12.25 kPa/m
Bentonite Slurry Grout:	12.5 lbs/gal	0.54 psi/ft
Bentonite Slurry Grout:	10.4 lb/US gal	0.54 psi/ft
Bentonite Slurry Grout:	1.14 kg/L	11.17 kPa/m
Bentonite Slurry Grout:	11.4 lbs/gal	0.49 psi/ft
Bentonite Slurry Grout:	9.5 lb/US gal	0.49 psi/ft

Reminder: In Table 12-4 the conversion from fluid density to pressure is multiplied by 9.8 for kg/L to kPa/m, 0.043 for lbs/gal to psi/foot and 0.052 for lbs/US gal to psi/foot.

13. Well Records, Documentation, Reporting & Tagging

Chapter Description

The reporting requirements in the *Wells Regulation* help to manage the groundwater resource and assist a person who is locating, repairing or abandoning a well. The documents provide a record of the well construction and subsurface formations which can be important in assessing spills or other environmental problems that may impair groundwater.

This chapter provides the requirements, exemptions and best management practices for:

- completing and keeping an accurate log of overburden and bedrock materials (geologic log) and field notes when constructing a well,
- completing, delivering and forwarding well records for both single wells,
- notifying the well owner or the Ministry of the Environment and Climate Change when environmental problems are identified during well construction, and

- affixing and protecting well tags.

The requirements listed in this chapter also do not apply to a person who performs an activity on a well that is exempt from the *Wells Regulation* (e.g., performing an inspection on a well). For further information see Chapter 3: Well Contractors & Well Technicians – Licences, Responsibilities & Exemptions.

Regulatory Requirements

Relevant Sections - The *Wells Regulation*

- Log and Field Notes – Section 12.1
- Well Tags – Sections 14.11 and 22
- Disinfection (Reporting Free Chlorine Residual) – Subsection 15(9)
- Information – Sections 16, 16.1 and 16.2
- Well Record (Single Well) – Section 16.3
- Well Record (Abandonment) – Section 16.5

The Requirements - Plainly Stated

The *Wells Regulation* requires a person constructing or abandoning a well to meet the following unless an exemption is provided in this section or Chapter 4: Well Contractors & Well Technicians – Licences, Responsibilities & Exemptions.

Overburden and Bedrock Log Requirements

Every person constructing a well must make a log of overburden and bedrock materials and have it available at the well site for inspection.

Exemptions - Overburden & Bedrock Log

The person constructing the well is exempted from the requirement to complete and keep a log of overburden and bedrock materials when:

- constructing a well by the use of a driven point,
- altering a well without deepening it, or
- only installing a pump.

The person abandoning the well is exempt from completing and keeping a log of overburden and bedrock materials for a well abandonment.

Reminder: Some of the reasons for the log of overburden and bedrock materials exemption are provided in the “Log and Field Notes” section of this chapter.

Field Notes Requirements

Every person constructing or abandoning a well is required to make and have available at the well site, for inspection, field notes that include an up to date record of the well construction or abandonment activities.

Well Tags for New Wells

Before the structural stage of a new cased well is complete, the person constructing the well must permanently affix a well tag, issued by the Ministry, to the outside of the casing or to a permanent structure associated with the well.

The affixed tag must be visible and must not be obstructed by the well cap, other well components or by equipment associated with the well.

Well Tags for Alterations to Existing Wells

Well Without a Well Tag

If an alteration (other than a minor alteration) is made to a cased well that does not have a well tag, a Ministry well tag must be obtained and affixed permanently to the outside of the casing or to a permanent structure associated with the well as described in "Well Tags for New Wells" in this Plainly Stated section.

Well With a Well Tag

During alterations to a cased well with a well tag, the well tag must be safeguarded and, if removed, it must be re-affixed permanently to the outside of the casing or to a permanent structure associated with the well upon completion of the alteration as described in "Well Tags for New Wells" in this Plainly Stated section.

Replacement of Damaged Well Tag and Well Record Completion

During an alteration, including a minor alteration, to a cased well with a well tag, if the existing well tag is broken, defaced, illegible or otherwise unusable, the person constructing the well must:

- remove the well tag and return it to the Director no later than the date that the well record is submitted to the Director (within 30 days after affixing the new well tag),
- before completing the alteration, affix a new well tag issued by the ministry as described in "Well Tags for New Wells" in this Plainly Stated section, and
- complete a well record with respect to the replacement of the well tag and submit the well record to the Director within 30 days after affixing the new well tag.

Well Tags – Removal during Well Abandonment

If there is a well tag on a well that is being abandoned, the person abandoning the well, often the well owner, must ensure that the well tag is removed as the first step in the well abandonment procedure and that it is returned to the Director within 30 days after its removal.

Reminder: See Chapter 15: Abandonment: How to Plug & Seal Wells for further information on the abandonment steps.

Well Tags – Defacing/Removing

It is not permitted to deface, alter, conceal or obstruct a well tag.

It is not permitted to remove a well tag that is affixed to a well unless the:

- the person has the written consent from the Director,
- the well tag on the well that is being altered is broken, defaced, illegible or otherwise unusable, or
- the well is being altered or abandoned (plugged and sealed).

It is not permitted to use a well tag issued by the Ministry except in accordance with the *Wells Regulation*.

Reminder: See Chapter 2: Definitions & Clarifications "Table 2-1" for the definition of "minor alteration" and and "Table 2-2" for clarification of the term "routine repair".

Reporting Free Chlorine Residual Records

Unless exempt and before the well is used as a source of water for human consumption, the person who disinfects and tests the well water for free chorine residual must provide the well purchaser with a written record of the test results

Reminder: See Chapter 8: Well Disinfection for further information.

Notification

Mineralized Water

Where a well is constructed and "mineralized water" is encountered, the person constructing the well must immediately notify the well purchaser and the owner of the land on which the well is located of the condition.

Natural Gas or Other Gas

Where a well is constructed and "natural gas" is encountered, the person constructing the well must immediately notify the well purchaser, the owner of the land on which the well is located, and the Director of the condition.

Reminder: See Chapter 2: Definitions & Clarifications "Table 2-1" for the definition of "mineralized water" and "Table 2-2" for clarification of the term "natural gas".

Information for the Well Purchaser

After Structural Stage

Unless the well purchaser otherwise directs, on the day that the well's structural stage is complete, the person constructing the well must:

- deliver an information package from the ministry to the well purchaser,
- provide a water sample, of at least one litre, to the well purchaser for visual examination, and
- measure the depth of the well in the presence of the well purchaser.

Pump Replacement

Unless the well purchaser otherwise directs, on the day that a pump, which includes associated equipment, is replaced in an existing well, the person installing the pump must:

- Deliver an information package from the ministry to the well purchaser.

Exemption - Information for the Well Purchaser

The person constructing the well does not have to meet the Information for the Well Purchaser requirements stated above if the person is performing a "minor alteration" on the well.

Well Record – Constructing Wells

On completion of a well's structural stage, the person constructing the well must:

- complete a well record for the well in full detail following the instructions and explanations on the record,
- within 14 days, deliver a copy of the well record to the well purchaser and the owner of the land on which the well is situated,
- within 30 days, forward a copy of the well record to the Director, and
- retain a copy of the well record for at least two years.

Exemption - Well Record for Construction

Minor Alteration or Pump Installation

A person who performs a "minor alteration" or installs a pump in a is not required to complete and submit a well record, unless there is a damaged well tag.

Reminder: The physical structure of a well is not significantly altered when a person installs a pump or performs a "minor alteration". In these cases, there is no major change to the structure of a well to be documented on a well record.

Reminder: For further information on replacing a damaged well tag, see "Replacement of Damaged Well Tag and Well Record Completion" in this Plainly Stated section

Reminder: See Chapter 2: Definitions & Clarifications, Table 2-1 for the definitions of "minor alteration" and see Table 2-3 for clarification of the term "pump."

Well Record – Abandonment of Well

When abandoning a well, the person abandoning the well, often the well owner, must:

- complete a well record for the well, in full detail, in accordance with the instructions and explanations on the record,
- within 14 days after the date on which the well construction equipment is removed from the site, deliver a copy of the well record to the owner of the land on which the well is situated, and

- within 30 days after the date on which the well construction equipment is removed from the site, forward a copy of the well record and any well tag that was removed from the well, to the Director.

Reminder: See the "Well Record Information" section of this chapter for further clarification on the term "person constructing the well". See the "Alterations," section of this Chapter of this chapter and see Chapter 11: Maintenance and Repair, "Requirements for Repairs and Alterations on Existing Wells" section for clarification of the term "alteration" and "minor alteration". See Chapter 2: Definitions and Clarifications, "Table 2-1" for definition and clarification of the terms "well's structural stage" and "minor alteration".

Relevant Standards

ASTM Standard D5434 - 09 – "Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock" (DOI: 10.1520/D5434-09)[1]

Key Concepts

Log And Field Notes

Every person constructing or abandoning a well is required to keep, and have available at the well site for inspection, field notes that include an up-to-date record of the construction activities. In many cases, a log of overburden and bedrock materials is also required.

Keeping accurate field notes is important for the following reasons:

- To complete the well record. The information transposed onto the well record may be used by the water well industry and environmental consultants seeking information on groundwater resources in an area (see "Well Record and Well Tag" section below).
- To document construction activities, field conditions, incidents and subsurface information prior to the completion of the well record.

Well Record & Well Tag

Well records provide construction and general water quantity and quality information. The well tag is a unique identifier that links the well in the field with the well record. Well records and tags are a notification system for use by the province, consultants, contractors and current or future well owners to:

- provide information on the groundwater and geology of an area, including:
  - groundwater availability,
  - general idea of depth to water,
  - possible flowing well conditions, and
- provide information on well construction in an area to help well technicians anticipate equipment needs and estimated costs,
- help to protect well owners and contractors from being open to enforcement action by the Ministry or civil action between parties,
- provide information to manage the groundwater resources,
- provide information for consultants and regulators on groundwater quality and quantity issues in an area,
- provide information on the location of wells and their construction details in case of spills, and
- assist in locating existing wells when purchasing a new property to ensure they are properly maintained or abandoned (plugged and sealed).

Information from well records is compiled at the Ministry. Together, with other databases and geographical information systems (GIS), the information provides an overview of groundwater and aquifers in Ontario, including:

- types of construction, uses and locations of wells in the province
- areas where natural gas, mineralized water or flowing wells occur,
- patterns, such as areas of natural gas and flowing wells, and
- location of low and high-yield aquifers.

Notification

The *Wells Regulation* does not require testing of water quality or gas during the construction of a well. Testing is typically completed after the well is ready to be put into operation by the well owner, an agent representing the well owner, or by another person.

If a person constructing a well identifies a gas or water quality issue, there may be an obligation on the person to report the issue. For example, the person constructing the well must immediately notify the well purchaser and the owner of the land on which the well is located if natural gas or mineralized water is encountered to:

- protect drinking water supplies,
- protect the environment and property,
- protect health and safety, and
- take additional precautions (e.g., equipment to remove or treat).

When a well is being constructed and natural gas is encountered, the person constructing the well must also immediately notify the Director (e.g., Spills Action Centre) of the condition.

Log And Field Notes

The *Wells Regulation* - Unless otherwise exempt, a person constructing a well is required to make a log of overburden and bedrock materials and field notes that include an up-to-date record of the construction or abandonment of the well during construction or abandonment of a well.

A log of the overburden and bedrock is not required if the person is:

- constructing a well by the use of a driven point,
- altering a well without deepening it,
- installing a pump (including associated equipment and alterations necessary to install the equipment), or
- abandoning a well.

Making visual observations of a formation is difficult when constructing a well by the use of a driven point. Also, as observations of subsurface formations were documented during the initial construction of a well, little information would be gained regarding subsurface formations when installing equipment or making most other alterations to an existing well.

Reminder: See Chapter 2: Definitions & Clarifications, Table 2-1 for the definition of the term "construct" and "pump" and Table 2-2 for clarification of the terms "well abandonment" and "driven point/use of a driven point".

The *Wells Regulation* - The field notes and, when required, the log of overburden and bedrock materials must be available for inspection at the well site during construction or abandonment of a well.

The person constructing the well should collect representative samples at measured depths and at intervals that will show the complete geological character of the hole. For example, formation samples could be collected at 1.5 m (5ft) intervals and at every change in formation materials. The log field notes should document the:

- Changes in formation materials including the top and bottom of each material/unit encountered,
- Observed characteristics of each formation unit,
- Depth to groundwater, water quality and gas observations,
- Materials and equipment used at the site and in the well, and
- Location information.

Reminder: Table 5-6 (Particle Sizes for Overburden Material) in Chapter 5: Constructing, Casing and Covering the Well can be used as an aid to describing overburden material.

Reminder: The person working at the abandonment of a well can assist the person abandoning the well, often the well owner, in completing the field notes. For clarification of the term "person abandoning the well" see the note in the "General Notes on Well Record Delivery" section of this chapter.

Best Management Practice – Additional Logging Activities

Hole logs, sampling logs and water level logs should be carefully kept and detailed. Properly kept and detailed logs help document construction activities, field conditions, incidents and subsurface information. The information can assist in:

- completing a well record accurately,
- completing a log prepared for various hydrogeological or geotechnical reports,
- offering assistance for dispute resolution, and
- supplementing the information on the well record form to assist in addressing problems associated with the well.

Sample Log Book Entry

As shown in Figure 13-1, observations of overburden and bedrock materials, construction, quantity and quality information are recorded in the log book. Observations recorded in the log book can then be reported on a well record. A copy of this log can be found in the "Tools" section of this chapter and copies can be made for use in the field.

Figure 13-1: Sample Log Book Entry

Figure 13-1 shows a sample log book entry

The upper left box states:

- Log
- Name of Well Technician – Joe Brown
- Date work complete (YY/MM/DD) – 5/07/21

The upper right box states:

- Measurements recorded in: metric

The Well Owner and Location Information box states:

- First Name – John
- Last Name – Smith
- Address of Well Location (Street Name and Number) – 62 Baseline Road
- Township – Zip
- Lot – 5
- Concession – 5
- County/District/Municipality – Hastings
- City/Town/Village –Smallville
- UTM Coordinates – NAD 83, Zone 17, Easting 738777, Northing 4938200

Geo – Log Box (located immediately below Well Owner and Location Information Box):
(Colours: White, Greg, Blue, Green, Yellow, Brown, Red, Black)
(Materials: Fill, Muck, Peat, Clay, Silt, Gravel, Stones, Boulders, Top Soil, Limestone, Fine Sand, Medium Sand, Coarse Sand, Dolomite, Shale, Sandstone, Slate, Quartzite, Granite, Greenstone)
(General Description: Loose, Porous, Dense, Packed, Cemented, Layered, Soft, Hard, Previously Dug or Bored, Previously Drilled, Wood Fragments)

- Headings – General Colour, Most Common Material, Other Materials, General Description, Comments, Depth (metres/feet): From – To
- Row 1 Below Headings – Brown, Top Soil, no other materials, loose, no comments, from 0 to o.45 metres
- Row 2 Below Headings – Grey, Clay, no other materials, Layered, no comments, from 0.45 to 7.62 metres
- Row 3 Below Headings – Brown, Coarse Sand, Stones, Porous, Lost Circulation, from 7.62 to 9.75 metres
- Row 4 Below Headings – Grey, Limestone, Gravel, Layered, no comments, 9.75 to 10.36 metres
- Row 5 Below Headings – Grey, Limestone, no other materials, Hard, no comments, 10.36 to 12.8 metres
- Row 6 Below Headings – Red/Green, Limestone, no other materials, soft, no comments, 12.8 to 13.1 metres
- Row 7 Below Headings – Grey, Limestone, no other materials, Hard, no comments, 13.1 to 16.76 metres
- Rows 8 to 14 are blank

Map of Well Location Box (located on the left side below Geo – log box):
(There are three examples of how to draw a map in rural areas, urban areas and lot/concession numbers not known)

- There is a plan view map showing the well located 4.1 kilometres north of highway 66 east, 300 metres east of Baseline Road, and 20.1 metres north of a building

Results of Well Yield Testing Box (located on the right side below Geo – log box):

- After test of well yield – clear and free of sand
- If pumping discontinued, give reason – none
- Pump intake set at – 15.24 metres
- Pumping rate - 26.5 litres per minute
- Duration of Pumping – 1 hour

- Final water level end of pumping – 11.3 metres
- Disinfected – yes
- Drawdown:
  - static water level: 2.4 metres,
  - 1 minute of pumping: 3.04 metres
  - 2 minute of pumping: 3.7 metres
  - 3 minute of pumping: 4.9 metres
  - 4 minute of pumping: 5.5 metres
  - 5 minute of pumping: 6.7 metres
  - 10 minute of pumping: 10.9 metres
  - 15 minute of pumping: 11.27 metres
  - 20 minute of pumping: 11.27 metres
  - 30 minute of pumping: 11.27 metres
  - 40 minute of pumping: 11.27 metres
  - 50 minute of pumping: 11.27 metres
  - 60 minute of pumping: 11.27 metres
- Recovery:
  - 1 minute of recovery: 11 metres
  - 2 minute of recovery: 10.36 metres
  - 3 minute of recovery: 8.5 metres
  - 4 minute of recovery: 7.9 metres
  - 5 minute of recovery: 7.01 metres
  - 10 minute of recovery: 6.7 metres
  - 15 minute of recovery: 5.5 metres
  - 20 minute of recovery: 3.96 metres
  - 30 minute of recovery: 3.04 metres
  - 40 minute of recovery: 2.4 metres
  - 50 minute of recovery: 2.4 metres
  - 60 minute of recovery: 2.4 metres

Construction Record – Screen Box (located below Results of Well Yield Testing Box):

- Outside diameter – Not filled out
- Material – Not filled out
- Slot # - Not filled out
- Diameter (From – to) – Not filled out

Construction Record – Casing Box (located below Construction Record – Screen Box):

- Inside diameter – 15.88 centimetres
- Open hole or material – steel
- Wall thickness – 0.477 centimetres
- Depth – from 0 to 11 metres
- Lengths of casing brought to job site in metres – 6,6 6,10, 6, 6, 3
- Lengths of casing installed in well in metres – 6, 6

Water Details Box (located below Map of Well Location Box):

- Water found at Depth – 12.8 metres
- Kind of water – fresh

Hole Diameter Box (located below Map of Well Location Box and to the right of the Water Details Box):

- Depth – from 0 to 11 metres with a diameter of 2.54 centimetres
- Depth – from 11 to 16.76 metres with a diameter of 15.56 centimetres

Annular Space Box (located below the Water Details Box):

- Depth – from 0 to 11 metres
- Material – bentonite
- Number of bags placed - 3

Well Owner’s Information Package (located below the Hole Diameter Box):

- Yes

- Date Package Delivered – 05/07/21

Well Record Exemption

There are exemptions for the completion of a well record for certain types of activities that involve water supply wells. The circumstances when a well record is not necessary are described in this section.

A person who performs a “minor alteration” or installs a pump in a well is not required to complete and submit a well record, unless there is a damaged well tag. The physical structure of a well is not significantly altered when a person installs a pump or performs a “minor alteration”. In these cases, there is no major change to the structure of a well to be documented on a well record.

Reminder: For further information on when to complete a well record for a damaged well tag, see “Replacement of Damaged Well Tag and Well Record Completion” in the “Plainly Stated” section of this chapter and the “Broken, Defaced, Illegible or Unusable Well Tags” section in this chapter.

Reminder: For further information on the terms “minor alteration”, “pump” and “well’s structural stage completion” see Chapter 2: Definitions & Clarifications, Table 2-1.

Best Management Practice – Completing and Submitting a Well Record in Special Cases

There are cases where the person constructing the well is required to affix a well tag to a well, but is not required to complete a well record. In the following instances, a well record should be completed and submitted:

- When a well tag is required to be affixed in the course of installing a pump.

The additional well records will help to:

- link and locate tagged wells in the field to well records,
- capture more information on wells, groundwater and geology for the Ministry’s water well database, and
- identify potential pathways for contamination.

Well Record Information

Unless exempt, a well will typically have multiple well records during its life. For example, a well could have a well record for construction, another if the well is altered and a third when it is abandoned.

When To Complete A Well Record For A Well

The *Wells Regulation* - Unless otherwise exempt, the person constructing the well must complete and submit a separate well record for a single well for the following well construction activities:

- New well construction
- Making an alteration to a well other than a minor alteration or installing a pump. This includes a well that was part of a group of wells that was originally reported on one well record, also known as a well cluster
- Making a minor alteration to a well or installing a pump in or on a well where the well tag is broken, defaced, illegible or otherwise unusable.

The *Wells Regulation* - Unless otherwise exempt, the person abandoning the well, often the well owner, must complete and submit a separate well record for the proper abandonment of a single well.

Reminder: See the “General Notes on Well Record Delivery” section in this chapter for further clarification on the term “person abandoning the well”. See Chapter 15: Abandonment: How to Plug & Seal Wells for information on proper well abandonment.

Reminder: For further information on the terms “minor alteration”, “pump” and “well’s structural stage completion” see Chapter 2: Definitions & Clarifications, Table 2-1. See the “Well Record Exemption” section in this chapter for further information on exemptions.

Considerations When Completing The Well Record

A person who is required to complete a well record must follow the instructions on the well record. The instructions for completing the well record after construction or abandonment of a single well are found on the back of the well record form. The well record includes instructions on how to observe and report the formation's texture (grain size), colour, hardness of the formations and other observations. See Figure 13-2 to Figure 13-14 for further information.

The person altering or abandoning an existing well must, as a minimum, complete the mandatory sections of the well record as stated in the instructions found on the back of the well record.

It is not necessary to complete a well record when installing a pump or performing a minor alteration, unless the well tag is broken, defaced, illegible or otherwise unusable (see "Broken, Defaced, Illegible or Unusable Well Tags," section on this chapter).

Reminder: Additional well record forms must be used if more information is required (see explanation of Page Number box in the "Completing the Well Record" section on the next page). Unless specified, all depths must be expressed from the ground surface at the time of construction.

Reminder: For the purposes of this manual, which only applies to water supply wells, filling out information on two or more wells on one well record is not permitted. There are special situations for test holes and dewatering wells where one cluster well record can be completed for two or more wells but this is not covered in this manual.

Reminder: If plugging and sealing a well immediately after installing the well due to a well being discontinued, then two separate well record forms that make one well record must be filled out: the first form (page 1 of 2) for the construction and the second form (page 2 of 2) for the plugging and sealing of the well.

Units Of Measurement

The single well record form and well record form for a "well cluster" allow for the use of Imperial units or metric units. A check box, found at the top of the well record, allows for the selection of metric or Imperial units. The unit system chosen must be used consistently throughout the well record. If a measurement is being reported in metres, it must be reported to the nearest tenth of a metre (e.g., 20.3 m).

Completing The Well Record

Figures 13-2 to 13-14 provide an explanation of how to complete a well record

Figure 13-2: Well Record - General Information

Well Tag Number

- This must match the well tag provided by the Ministry that is permanently affixed to the casing or another structure associated with the well. The well tag sticker provided in the well tag package should be used where a new well tag is affixed to the well to prevent errors in copying the number.

Page Number

- If more information needs to be recorded than can fit on one well record form, then an additional well record form must be filled out and labelled page 2.
- If there are two pages, the forms would read "Page 1 of 2" and "Page 2 of 2", respectively
- Any additional pages must indicate the same well tag number
- All pages would constitute a single well record

Measurements (Metric or Imperial)

- The box for the chosen unit system must be checked
- Measurements must be recorded in the units specified in the well record sections
- The unit system chosen must be used consistently throughout the well record

Figure 13-3: Well Record - Well Owner Infomation

Well Owner Information

- First name

- Last Name / Organization
- E-mail Address
- Well Constructed by owner
- Mailing Address (Street Number/Name)
- Municipality
- Province
- Postal Code
- Telephone No.(inc. area code)

Note:

- All applicable sections must be completed
- This can be information on the owner of the land on which the well is located or the well purchaser
- If the well owner is an organization or company, the word “Organization” must be circled and the name of the entity must be printed in the “Last Name/Organization” field

Information Package

- Well owner's information package delivered (Yes / No)
- Date Package Delivered
- Date Work Completed

Note

- This section must be completed
- This section is filled out once the well is complete and the well purchaser has been provided with a copy of the Well Owner’s Information package
- “Yes” can be checked off

Figure 13-4: Well Record - Well Contractor And Well Technician

Well Contractor and Well Technician Information

- Business Name of Well Contractor
- Well Contractor's License No.
- Business Address (Street Number/Name)
- Municipality
- Province
- Postal Code
- Business E-mail Address
- Business Telephone No. (inc. area code)
- Name of Well Technician (Last Name, First Name)
- Well Technician's License No.
- Signature of Technician and/or Contractor
- Date Submitted

This box provides information about the individual and company who constructed the well and must be fully completed by the person constructing the well except for the following situations:

- If the person who constructed the well is an exempted professional who is permitted to construct wells without a licence (see Chapter 3: Well Construction Licences: Obtaining, Maintaining & Exemptions), the person must record his/her name in the “Name of Well Technician” box, sign the “Signature of Technician” and provide his/her company’s particulars
- If the well was constructed by the owner of the land, a member of the person’s household or a person working without compensation for the owner of the land, the person constructing the well must record his/her name in the “Name of Well Technician” box and sign in the “Signature of Technician and/or Contractor” box. The words “Well Technician” and “Contractor” should be crossed out and the changes initialled
- If the well was abandoned, information about the person who works at the well abandonment may be recorded in this section

Figure 13-5: Well Record - Well Location

Well Location

- Address of Well Location (Street Number/Name)
- Township
- Lot
- Concession
- County/District/Municipality
- City/Town/Village
- Province: Ontario
- Postal Code
- UTM Coordinates: NAD 83
- Zone
- Easting
- Northing
- Municipal Plan and Sublot Number
- Other

Note:

- It is important to accurately record the location the well. Inaccurate location information on the well record can lead to problems locating the well in the field. Location information includes the following:
  - Street number/name, city/town/village must be provided if available
  - Original geographic township, concession and lot must be reported if the well is located in an area where such information exists
  - Fire locator number may also be recorded in the “Other” box
  - UTM Coordinates must be recorded using a GPS unit
  - Municipal plan and sublot numbers may be provided if available
  - Current county or district/amalgamated municipality or township, if reported, should be entered under “County/District/Municipality.” For example, in the County of Frontenac/Township of South Frontenac, the Township of South Frontenac is the amalgamated township. If the townships were amalgamated, the old and new township names should be included, if known

Figure 13-6: Well Record - Map Of Single Well Location

Map of Well Location

- A map showing all property boundaries must be provided. At least two measurements sufficient to locate the well in relation to fixed points must be provided. For example:
  - In rural areas, one distance should be taken from a road and other from either a road or a township lot line (example A, below)
  - In a village, town or city, both distances should be taken from named streets (example B)
  - In areas where it is difficult to obtain lot and concession numbers, sufficient information should be supplied in the diagram so that the well can be related to a known unit such as a main highway, railway, or municipality (examples C and D)
- Detailed drawings can be provided as attachments on paper no larger than the size of the well record (8.5 inches by 14 inches)
- A North arrow must be included on the diagram.
- The “Comment” box may be used to record any additional information such as the elevation of the well. It is also an appropriate location to state whether or not hydrofracturing or blasting was done at the time of construction (see the BMP below)
- The “Comment” box is also an appropriate place to reference the original well tag when a well tag is replaced and original well record number for an alteration
- It is important to review the directions given on the back of the well record

Best Management Practice – Compiling Details about Hydrofracturing or Blasting Techniques

If hydrofacturing or blasting techniques were used, the person completing the well record should provide details on a separate sheet. The sheet should be attached to the well record and copies of the attachment should be included with each copy of the well record.

Figure 13-7: Well Record - Overburden And Bedrock Materials/ Abandonment Sealing Record

Overburden And Bedrock Materials/ Abandonment Sealing Record

- If a person is plugging and sealing a well, the abandonment details must be recorded in this section. The type of abandonment barrier (sealant) used must be indicated in the "General Description" column and the depth of sealant must be indicated in the "Depth" column
- If a person is constructing a well:
  - For each formation encountered during construction, words chosen from the lists provided on the back of the well record that best describe the formation on the basis of general colour, most common material, other materials and general description of the formation must be used
  - Instructions are found on the back of the well record and shown below

    General Colours:

    - White
    - Grey
    - Blue
    - Green
    - Yellow
    - Brown
    - Red
    - Black

    Materials:

    - Fill
    - Muck
    - Peat
    - Clay
    - Silt
    - Gravel
    - Stones
    - Boulder
    - Top Soil
    - Limestone
    - Fine Sand
    - Medium Sand
    - Coarse Sand
    - Dolomite
    - Shale
    - Sandstone
    - Slate
    - Quartzite
    - Granite
    - Greenstone

    General Description:

    - Loose
    - Porous
    - Dense
    - Packed
    - Cemented
    - Layered
    - Soft
    - Hard
    - Previously Dug or Bored
    - Previously Drilled
    - Wood Fragments

    Clay: Composed of very fine particles. Forms Dense hard lumps or clods when dry and a very elastic putty-like mass when wet. It can be rolled between fingers to form a long, flexible ribbon.

    Silt: Grain size, midway between sand and clay. It may form clods which, when broken, feel soft and floury. When moist, it will form a cast that can be handled freely without breaking. Rolled between thumb and finger, it will not "ribbon" but will

give a broken appearance.

Sand: Grain are loose and granular and may be seen and felt readily. Squeezed in the hand when dry, in falls apart when the pressure is released. Squeezed when moist, it will form a cast that will crumble when touched. Should be listed as fine, medium ro coarse.

Gravel: Rock fragments greater than 0.3 cm in diameter

- An example of a completed section is provided below and found on the back of the well record:

Example of a Completed Section

General Colours	Most Common Material	Other Materials	General Descriptions	Depth From	Depth To
Brown	Top Soil	n/a	n/a	0	0.6
Grey	Coarse Sand	Gravel, Silt	Loose, Wood Fragments	0.6	13.0
Blue	Clay	Silt, Stones	Dense	13.0	25.0
Brown	Fine Sand	Clay	n/a	25.0	31.0

Figure 13-8: Well Record - Well Use

Well Use

Well use
: means the intended purpose at the time of construction

- Public – e.g., school, religious organization, town hall, recreation centre, campground, trailer park
- Domestic – for private residential homes
- Livestock – used for farms and feed lots
- Irrigation – used for agricultural activities, golf courses and greenhouses
- Industrial – factories using water for industrial purposes but not incorporation into a food product or mineral exploration
- Commercial – e.g., car wash, snow making, restaurant, bottled water or other beverage making
- Municipal – water supply for cities and towns
- Cooling & Air Conditioning – e.g., an open or closed loop earth energy system (heat pump)
- Not used – constructed for some purpose, not being used and will be maintained for future use. A second box must be checked to indicate the intended use
- For the purposes of test holes and dewatering wells the following will apply:
  - Test Hole – a well that is made to test or to obtain information in respect of groundwater or an aquifer and is not intended as a source of water for agriculture or human consumption
  - Dewatering – a well that is not used or intended for use as a source of water for agriculture or human consumption and that is made to lower or control the level of groundwater in the area of the well, or to remove materials that may be in the groundwater
  - Monitoring – a well that is made to test or to obtain information in respect of groundwater or an aquifer and is not intended as a source of water for agriculture or human consumption
  - Other – e.g., communal such as water supply that serves a small rural sub-division
- In the situation where a test hole or dewatering well for a sub-division is then going to be used as a domestic water supply, all boxes that apply should be checked (original and future purposes)
- For the purposes of the *Wells Regulation* and the well record completion, “Test Hole” and “Monitoring” are synonymous

Figure 13-9: Well Record - Method Of Well Construction & Status Of Well

Status of Well

This section is used to identify the status of the well at the time of completion. All boxes that apply should be checked.

- Water Supply
- Replacement Well
- Test Hole
- Recharge Well
- Dewatering Well
- Observation and/or Monitoring Hole
- Alteration (Construction)

- Abandoned, Insufficient Supply
- Abandoned, Poor Water Quality
- Abandoned, Other, specify
- Other, specify

Method Of Construction

The construction method used is identified by checking the appropriate box or boxes if more than one system is used (e.g., rotary conventional and air percussion). If the method used is not part of the list, the “Other, specify” box must be checked and the method must be described (e.g.,sonic or direct push)

- Cable Tool
- Rotary (Conventional)
- Rotary (Reverse)
- Boring
- Air Percussion
- Diamond
- Jetting
- Driving
- Digging
- Other, specify

Figure 13-10: Well Record - Construction Record - Casing

- Inside Diameter (cm/in)
- Open Hole Or Material (Galvanized, Fibreglass, Concrete, Plastic, Steel)
- Well Thickness(cm/in)
- Depth From (m/ft)
- Depth To (m/ft)

Construction Record - Casing

- Material means type of manufactured material used to make the casing
- An interval without casing must be reported as “open hole”
- Wall thickness means minimum or nominal wall thickness
- A new line should be filled in for every change in casing (e.g., material, inside diameter or wall thickness) or open hole diameter
- All depths must be expressed from the ground surface at the time of construction. The amount of casing above the ground surface should be expressed with “+”. For example, a contractor installs casing +0.6 m above the ground surface and extends the casing to 7 m below the ground surface
- Joint and packer depths from ground surface should be recorded (see the best management practice below)

Best Management Practice – Recording Joint and Packer Locations

Casing joint and packer locations (depths) from ground surface should be recorded in the “Construction Record – Casing” box of the well record.

Figure 13-11: Well Record - Construction Record - Well Screen And Hole Diameter

Construction Record - Screen

- Outside Diameter (cm/in)
- Material (Galvanized, Plastic, Steel)
- Slot No.
- Depth From (m/ft)
- Depth To (m/ft)

Note:

- Material can also include pre-packed well screens and unsealed concrete tiles or other material installed in a well to filter out particulate matter
- Slot number as provided by the manufacturer must be recorded
- Depth includes top of riser pipe, if applicable
- All depths must be expressed from the ground surface at the time of construction

Hole Diameter

- Depth From (m/ft)
- Depth To (m/ft)
- Diameter (cm/in)

Note:

- The diameter and depth of the hole must be recorded using the measurement unit system chosen at the top of the well record (metric or Imperial)
- The depth of the hole relative to the ground surface must be recorded

Figure 13-12: Well Record - Annular Space

- Depth Set at From (m/ft)
- Depth Set at To (m/ft)
- Type of Sealant Used (Material and Type)
- Volume Placed (m^3/ft^3)

Annular Space

- "Depth set at" relative to the ground surface must be recorded
- The type of suitable sealant installed in the annular space must be recorded
- "Depth set at" and "volume placed" in the measurement units indicated at the top of the well record (metric or Imperial) must be recorded
- The volumes of sealant placed must be shown as either m^3 or ft^3
- "Volume placed" (see Chapter 6: Annular Space & Sealing, Calculating Amount of Material Required section) must be calculated
- Type of Sealant Used:
  - "Material" means sodium bentonite, cement, concrete and other suitable sealants
  - "Type" means trademark name of the product

Best Management Practice – Recording all Material Installed in Annular Space

Within the annular space box, the person constructing the well should record where any clean washed sand or gravel has been installed in the well's annular space (e.g., around well screen).

Figure 13-13: Well Record - Water Details

- Water found at Depth (m/ft) Gas
- Kind of Water: Fresh; Untested; Other (specify)

Water Details

- The distance from the ground surface to the water bearing formation(s), or horizon(s), where water is found must be recorded. Also, if naturally occurring or other gas is found then it must be recorded
- The same measurement unit system chosen at the top of the well record (metric or Imperial) must be used consistently
- The correct box for the type of water found must be checked:
  - "Fresh water" means that there are no taste, odour or colour issues with the well water in the field (Field testing equipment should be used instead of tasting well water to avoid drinking potentially contaminated or non-potable water)
  - "Other" could include mineralized water (see definition in Chapter 2: Definitions & Clarifications, Table 2-1)

- If gas is encountered, the Ministry of the Environment and Climate Change must be contacted (see "Notifications" section in this chapter)

Figure 13-14: Well Record - Well Yield

- After test of well yield, water was:
  - Clear and sand free
  - Other, specify
- If pumping discontinued, give reason:
- Pump intake set at (m/ft)
- Pumping rate (l/min / GPM)
- Duration of pumping hrs + min
- Final water level end of pumping (m/ft)
- If flowing give rate (l/min / GPM)
- Recommended pump depth (m/ft)
- Recommended pump rate (l/min / GPM)
- Well production (l/min / GPM)
- Disinfected? (Yes / No)
- Draw Down time (min)
- Draw Down Water Level (m/ft)
- Recovery Time (min)
- Recovery Water Level (m/ft)

Disinfected?

- Typically will be "yes" for water supply wells unless exempted such as a flowing well

Results of Well Yield Testing (Static Level Box)

- When a static water level measurement is required, it must be recorded in the "static level" box in this section
- See Chapter 11: Yield Test for information on testing the yield of the water in a well

Well Record Delivery

New Well Construction - Well Record Delivery

The *Wells Regulation* - A copy of the completed well record must be delivered by the person constructing the well to the well purchaser and land owner within 14 days after the date on which the well's structural stage is complete.

The *Wells Regulation* - A copy of the completed well record must be forwarded by the person constructing the well to the Ministry at the Wells Help Desk, Ministry of the Environment and Climate Change, 125 Resources Road, Toronto Ontario M9P 3V6 within 30 days after the date on which the well's structural stage is complete.

The *Wells Regulation* - A completed well record must be kept by the person constructing the well for at least two years.

Alterations - Well Record Delivery

The *Wells Regulation* - A copy of the completed well record must be delivered by the person constructing (altering) the well to the well purchaser and land owner within 14 days after the date on which the well's structural stage is complete

The *Wells Regulation* - A copy of the completed well record must be forwarded by the person constructing (altering) the well to the Ministry at the Wells Help Desk, Ministry of the Environment and Climate Change, 125 Resources Road, Toronto Ontario M9P 3V6 within 30 days after the date on which the well's structural stage is complete.

The *Wells Regulation* - A completed well record must be kept by the person constructing the well for at least two years.

Reminder: Generally, a well record is not required to be completed for a minor alteration or the installation of a pump. If a well tag is broken, defaced, illegible or otherwise unusable, however, a well record is required to be completed with respect to the required replacement of the well tag, even during a minor alteration. See the "Broken, Defaced, Illegible or Unusable Well Tag" section later in this chapter for further information on the well tag replacement and the well record completion and submission requirements in this case.

Reminder: Further information on the "well's structural stage completion", "minor alteration" and "pump" can be found in Chapter 2: Definitions & Clarifications, Table 2-1. The term minor alteration is also discussed in the "Well Tags" section in this chapter.

Abandonment - Well Record Delivery

The *Wells Regulation* - On completion of the abandonment of a well, the person abandoning the well, often the well owner, must:

- within 14 days after the date on which the well construction equipment is removed from the site, deliver a copy of the well record to the owner of the land on which the well is situated; and
- within 30 days after the date on which the well construction equipment is removed from the site, forward a copy of the well record and any well tag that was removed from the well, to the Director.

Reminder: See Chapter 15: Abandonment: How to Plug & Seal Wells for information on proper well abandonment.

General Notes On Well Record Delivery

Reminder: Well records are forwarded to the Director c/o the Wells Help Desk, Ministry of the Environment and Climate Change, 125 Resources Road, Toronto Ontario M9P 3V6.

Reminder: Examples of well construction equipment include: a grout pump, a tremie pipe, casing removal equipment such as a cutter or torch, a drilling rig, a boring rig, an excavator, a pump truck and drive point equipment.

Reminder: The person abandoning the well is considered:

- The person constructing a well when the well has been discontinued prior to the completion of the well's structural stage and it must be immediately abandoned
- The well purchaser for a dry well that must be immediately abandoned
- The well owner for a well that must be immediately abandoned because it produces "mineralized water" or water that is not potable.
- The well owner for a well that must be immediately abandoned because it:
  - is not in use or being maintained for future use as a well
  - contains natural gas or other gas and the gas is not managed in a way that prevents any potential hazard
  - permits the movement of materials including natural gas and contaminants and the movement may impair the quality of any waters
  - is constructed in contravention of the *Wells Regulation* requirements for location, methods, materials or standards and measures taken to rectify the problem have failed

Reminder: For information on when to abandon a well, see Chapter 14: Abandonment: When to Plug & Seal Wells.

Well Record Copies

The following best management practices have been developed to ensure well records are provided to the various parties and properly kept and stored.

Best Management Practice – Keeping Well Record

Any well record for construction, alteration or abandonment should be kept longer than the 2 years required as this assists in responding to future enquiries regarding the well or other wells in the area.

Best Management Practice – Extra Well Record Copies

If there are an insufficient number of true copies of the well record (e.g., if the well purchaser and owner of the land are different), the person completing the well record should provide the original well records to the owner of the land and the Ministry and provide a photocopy, or scanned copy, of both sides of the well record and any attachments to the well purchaser to meet the well record submission requirements. The person completing the well record should certify any extra copies of the well record at the time of well construction.

Best Management Practice – Make Extra Copies of the Well Record

It is important that the well owner make additional copies of the well record and keep the copies in a location where they can be easily found, such as one or more of the following:

- Beside the pumping equipment
- With mortgage papers
- Land property survey
- In a safety deposit box
- Properly filed at the business' head office
- Electronically scanned and stored in a computer storage device and filed with other important papers

It is also recommended that all well records for wells, including the abandoned wells, be provided when the property is transferred to a new owner. The new well owner will then have knowledge of the location and status of the wells on the property to prevent:

- well damage from any new excavations or building on the property, and
- well contamination from any new source of contaminants constructed or placed near a well.

Well Tags

The well tag is a unique identifier that links one well(s) in the field with the well record.

Figure 13-15: Sample Well Tag

Well Tags for a Well

The *Wells Regulation* - Before the structural stage of a new cased well is completed, the person constructing the well must permanently affix a well tag, issued by the Ministry, to the outside of the casing or to a permanent structure associated with the well. The affixed tag must be visible and must not be obstructed by the well cap, other well components or by equipment associated with the well.

The *Wells Regulation* - If an alteration, other than a minor alteration, is made to a cased well without a well tag, the person making the alteration must obtain and affix a Ministry well tag, as described above, before the alteration is completed.

Reminder: A permanent structure associated with the well can include a protective well cover or flush-mounted well pit (vault), for example.

Reminder: The Ministry provides a well tag sticker with each new well tag. The sticker has the same number or code as the well tag.

Reminder: To link the well in the field with the well record, the person constructing (altering) the well must:

- place the well tag sticker for the new tag on the well record completed for the alteration or
- copy and record the alphanumeric code from the well tag on the well record completed for the alteration

In order to reduce the risk of transcription errors, it is recommended to use the well tag sticker, if available.

Definition - The *Wells Regulation* defines a "minor alteration" as any of the following:

- routine repair or maintenance,
- the installation of monitoring, sampling or testing equipment used to test the yield of the well or the aquifer,
- the installation of a pump in a test hole, or
- the installation of a well cap or watertight well cover

Best Management Practice – Completing Well Record When Affixing a Well Tag

A well record should be completed and submitted to ensure that the well in the field is linked to the well record when a well tag is affixed as a result of installing a pump and associated pumping equipment or altering the well to accommodate the pump or associated pumping equipment.

Reminder: See the “Broken, Defaced, Illegible or Unusable Well Tags” section in this chapter for further requirements on replacing a well tag when conducting a minor alteration to a well.

How To Attach The Well Tag To The Casing

If the well tag is to be permanently affixed to the well casing, it is preferable to use a stainless steel strap. If strapping is not feasible, the tag may be tack welded into place. Strapping and welding rods made of stainless steel are essential to prevent corrosion. The well tag can also be lag bolted or screwed into concrete, affixed to a metal bracket, or affixed using a clamping gear.

If a strap is used, it should be placed through the slots in the tag, wrapped around the casing and crimped tight with a strapping tool. If tack welding, the four corners of the tag should be welded to the casing using stainless steel welding rods. If lagging or screwing is the selected method, the drill holes should not fully penetrate through the well casing. This would compromise the casing integrity.

Figure 13-16: Attaching The Well Tag To The Casing

The diagram shows a strapping tool used to affix metal straps and a well tag to a well. See description in the above text. Figure 13-17 shows the well tag affixed to the well using the metal strapping.

Attaching Well Tags In Various Scenarios

Scenario #1: The Casing Of The Well Extends Above Grade And The Pump Is Not Positioned Over The Casing

This scenario would include wells with a submersible pump or jet pump. The tag is affixed around the casing with a stainless steel strap (see Figure 13-16 for strapping tool) or, if strapping is not possible, the tag is welded into place with stainless steel rods or lag bolted/screwed into the concrete casing (Figure 13-18). In the case of a driven point well, when the casing is not higher than 40 cm above the ground level, a highly visible marker is also required to be placed near the well (see Figure 13-19).

Figure 13-17: Example Of Properly Attached Well Tag

Figure 13-18: Threaded Screws Attaching Well Tag To Concrete Casing

Figure 13-19: Well Tag Affixed To A Driven Point Well

Scenario #2: The Casing Sticks Up And The Pump Is Located Directly Over The Casing

Figure 13-20: Well Tag On Equipment Associated With The Well As Close As Possible To The Casing

This scenario would include wells with a vertical turbine pump, or another type of pump positioned directly over the casing. Some methods of affixing the well tag include setting/screwing or lag bolting the well tag into the concrete well slab as close as possible to the casing. The well tag must remain visible and protected from wear and tear.

Scenario #3: The Pump And Casing Are Located In A Pump House

Figure 13-21: Inside Pump House With Visible Well Tag On Associated Well Equipment

The presence of a well house does not affect the placement of the well tag. The tag location depends on whether the pump is positioned directly over or offset from the casing. The directions in Scenario #1 or #2 should be followed, whichever is appropriate. In addition, the well owner is encouraged to post a sign on the outside of the pump house, either next to the door or on the door, indicating the well tag number.

Broken, Defaced, Illegible Or Unusable Well Tags

The *Wells Regulation* - A person conducting an alteration, including a minor alteration, on a well with a well tag that is broken, defaced, illegible or otherwise unusable must:

- remove the well tag and return it to the Director,
- obtain a new well tag from the Ministry and, before the alteration is completed, permanently affix the well tag to the outside of the casing or to a permanent structure associated with the well, at a point where the well tag will be visible and will not be obstructed by the well cap, by other components of the well or by equipment associated with the well, and
- within 30 days after the new well tag is affixed to the casing, complete a well record with respect to the replacement of the well tag and forward a copy of the well record and the original well tag to the Director.

Best Management Practice – Referencing the Original Well Tag Number

When a well tag is replaced, the new well record for the replacement of a well tag should reference the original well tag number if it is available.

Best Management Practice – Completing Well Record When Replacing a Damaged Well Tag

When filling out a well record for the replacement of a damaged well tag in the course of a minor alteration the person altering the well should:

- provide as much information as possible on the Ministry well record form in addition to information relating to the replacement of the well tag, and
- provide the well record to the well owner and well purchaser

If legible, the old well tag number should be indicated on the well record. The person performing the alteration should provide a copy of the well record to the well purchaser and the land owner. Well owners will therefore be informed that their well tag has been changed and possess all well records for their well. In these cases, the requirements related to forwarding the well record to the Ministry apply.

Figure 13-22: Before - Well Tag Must Be Replaced

Figure 13-23: After - Well Tag Replaced

Figure 13-22 and Figure 13-23 show the before and after of a broken well tag that was replaced when a minor alteration (e.g., well cap removal) was made to the well. In this case, the well cap and conduit pipe were also upgraded to remove a pathway for foreign materials to enter the well.

Safeguarding The Well Tag

The *Wells Regulation* - During alterations to a cased well with a well tag, the well tag must be safeguarded and, if removed, it must be re-affixed permanently to the outside of the casing or to a permanent structure associated with the well, upon completion of the alteration.

Well Tag Restricitons

To help locate and identify a well with a well tag in the field, the *Wells Regulation* provides the following well tag requirements that all persons must adhere to.

The *Wells Regulation* - It is not permitted to deface, alter, conceal or obstruct a well tag.

The *Wells Regulation* - It is not permitted to remove a well tag that is affixed to a well or a structure associated with the well unless:

- the person has the written consent from the Director,
- the well tag on the well that is being altered is broken, defaced, illegible or otherwise unusable, or
- the well is being altered or properly abandoned (plugged and sealed)

The *Wells Regulation* - It is not permitted to use a well tag issued by the Ministry except in accordance with the *Wells Regulation*.

Reminder: If no alteration to a well takes place, a person must not affix a Ministry issued well tag to the well or a structure associated with the well as this is not a permitted use of the well tag under the *Wells Regulation*. In other words, to identify unaltered existing wells in the field a person should use unique field numbers and must not use well tags.

Notifications

The *Wells Regulation* does not require testing of water quality or gas during the construction of a well. Testing is typically completed after the well is ready to be put into operation by the well owner, an agent representing the well owner, or by another person. Advice and best management practices on safety considerations and identifying contaminants including gas are provided to persons constructing wells in Chapter 5: Constructing the Hole, Casing & Covering Well. If a person constructing a well identifies a gas or water quality issue; however, then there may be an obligation on the person to report the issue.

Natural Gas

The *Wells Regulation* - When natural gas is encountered, the person constructing the well must immediately notify the well purchaser, the owner of the land on which the well is located and the Director.

For further information on natural gas, see Chapter 2: Definitions & Clarifications, Table 2-3.

To report an observation of natural gas, the person could use the information in the "Best Management Practice - Encountering Contamination, Mineralized Groundwater or Gas" in this section.

Mineralized Water

The *Wells Regulation* - If a person constructing a water supply well (e.g., drinking water well) notices mineralized water, the person must notify the well purchaser and the owner of the land on which the well is situated that the condition exists.

The information is important to allow for the determination of the type of treatment system that may be needed, the potential for mineralized water to impair other fresh groundwater zones and whether a written consent from the Director to not abandon the well is necessary.

Information For Well Purchaser

The *Wells Regulation* - Unless the well purchaser otherwise directs, on the day that the structural stage is complete, the person constructing the well, other than a minor alteration, must:

- deliver an information package from the Ministry to the well purchaser,
- provide a water sample, of at least one litre, to the well purchaser for visual examination, and
- measure the depth of the well in the presence of the well purchaser.

Unless the well purchaser otherwise directs, on the day that a pump (which includes associated equipment) is replaced in an existing well, the person installing the pump must:

- deliver an information package from the Ministry to the well purchaser.

Before the well is used as a source of water for human consumption, the person who disinfects and tests the well water for free chorine residual must provide the well purchaser with a written record of the test results (see Chapter 8: Well Disinfection).

Best Management Practice – Informing the Well Owner of Nearby Sources of Contamination

The well owner should be immediately informed if it becomes known that the existing well is located on or near a source of contamination (see Chapter 4: Siting the Well).

Best Management Practice – Reporting Detection of Colour, Odour or Other Problems

In addition to the requirement to record observed water quality problems on the well record, detection of colour, odour or other problems with the well water should be reported to the well purchaser and land owner, and the observations should be recorded on the well record. To protect all parties, a written copy of the notification of water problems should be provided to the well purchaser and land owner. A copy of the written notification should also be retained.

Reminder: It is important to use field testing equipment instead of tasting well water to avoid drinking potentially contaminated or non-potable water.

Best Management Practice – Educating the Well Owner

The well owner has responsibilities under the *Wells Regulation* for every well on his/her property. In some cases, this may be the well owner's first well and the well owner may not know how to maintain the well and protect the water supply. The person constructing the well should explain the following to the well owner using plain language:

- How to care for a well
- The requirements for maintaining and abandoning the well
- The construction details, water quantity, water quality and other sections of the well record (for new wells or altered wells)
- The next steps such as pump installation (for new wells)
- The importance of reviewing the Ministry information package about wells
- The importance of keeping the well accessible for future maintenance
- Any other information, including the *Wells Regulation* and relevant internet websites

If unexpected problems with water quality or a gas, which is not considered natural gas, are observed during well construction or abandonment, the person completing the work should consider the following best management practice.

Best Management Practice – Encountering Contamination, Mineralized Groundwater or Gas

If unexpected contamination or gas is encountered in the construction (including alteration) of the well, the person who is working at the well should stop work immediately to reduce serious dangers to the site crew, well owner and the environment.

To meet the obligation of reporting natural gas to the Director, the person constructing the well should contact the Ministry of the Environment and Climate Change through the Ministry's Spills Action Centre (SAC) at . The SAC is available to take calls 24 hours a day, 365 days a year and alerts various Ministry organizations including the Director. In addition, the local fire department should be contacted.

Unexpected contamination or gas [1] that is encountered in a well should be reported to the well owner and SAC or the Ministry of the Environment and Climate Change local district office (see Resources at the end of this manual for contact information).

The Ministry can offer assistance and notify other agencies to help reduce serious dangers to the site crew, well owner and the environment.

If water quality problems associated with the groundwater (e.g., turbidity), other than "mineralized water" are observed, the person who is working at the well should immediately inform the well purchaser and the owner of the land on which the well is situated. This information can be used to determine if the water quality issues could: cause any impairment to other waters, affect

sample results, treatment systems, or impact the well and other equipment associated with the well (e.g., corrosive groundwater on casing).

Tools

Figure 13-24: Example Of The Front Page Of A Log

Figure 13-24 shows a sample of the front page of a log.

The upper left box states:

- Log
- Name of Well Technician –
- Date work complete (YY/MM/DD) –

The upper right box states:

- Measurements recorded in: metric or imperial

The Well Owner and Location Information box states:

- First Name –
- Last Name –
- Address of Well Location (Street Name and Number) –
- Township –
- Lot –
- Concession –
- County/District/Municipality –
- City/Town/Village –
- UTM Coordinates – NAD 83, Zone, Easting, Northing

Geo – Log Box (located immediately below Well Owner and Location Information Box):
(Colours: White, Greg, Blue, Green, Yellow, Brown, Red, Black)
(Materials: Fill, Muck, Peat, Clay, Silt, Gravel, Stones, Boulders, Top Soil, Limestone, Fine Sand, Medium Sand, Coarse Sand, Dolomite, Shale, Sandstone, Slate, Quartzite, Granite, Greenstone)
(General Description: Loose, Porous, Dense, Packed, Cemented, Layered, Soft, Hard, Previously Dug or Bored, Previously Drilled, Wood Fragments)

- Headings – General Colour, Most Common Material, Other Materials, General Description, Comments, Depth (metres/feet): From – To

Reminder: Figure 13-24 and Figure 13-25 can be photocopied front to back and used in the field.

Figure 13-25: Example Of The Back Page Of A Log

Figure 13-25 shows a sample of the back page of a log.

Map of Well Location Box (located on the left side below Geo – log box):
(There are three examples of how to draw a map in rural areas, urban areas and lot/concession numbers not known)

Results of Well Yield Testing Box (located on the right side below Geo – log box):

- After test of well yield – clear and free of sand or other
- If pumping discontinued, give reason –
- Pump intake set at –
- Pumping rate
- Duration of Pumping –
- Final water level end of pumping –
- Disinfected – yes or no

- Drawdown:
    - static water level:
    - 1 minute of pumping:
    - 2 minute of pumping:
    - 3 minute of pumping:
    - 4 minute of pumping:
    - 5 minute of pumping:
    - 10 minute of pumping:
    - 15 minute of pumping:
    - 20 minute of pumping:
    - 30 minute of pumping:
    - 40 minute of pumping:
    - 50 minute of pumping:
    - 60 minute of pumping:
- Recovery:
    - 1 minute of recovery:
    - 2 minute of recovery:
    - 3 minute of recovery:
    - 4 minute of recovery:
    - 5 minute of recovery:
    - 10 minute of recovery:
    - 15 minute of recovery:
    - 20 minute of recovery:
    - 30 minute of recovery:
    - 40 minute of recovery:
    - 50 minute of recovery:
    - 60 minute of recovery:

Construction Record – Screen Box (located below Results of Well Yield Testing Box):

- Outside diameter –
- Material –
- Slot # -
- Diameter (From – to) –

Construction Record – Casing Box (located below Construction Record – Screen Box):

- Inside diameter –
- Open hole or material –
- Wall thickness –
- Depth – from to
- Lengths of casing brought to job site in metres –
- Lengths of casing installed in well in metres –

Water Details Box (located below Map of Well Location Box):

- Water found at Depth –
- Kind of water – fresh, untested, other

Hole Diameter Box (located below Map of Well Location Box and to the right of the Water Details Box):

- Depth – from/to/diameter

Annular Space Box (located below the Water Details Box):

- Depth –
- Material –
- Number of bags placed –

Well Owner's Information Package (located below the Hole Diameter Box):

- Yes or No
- Date Package Delivered –

Reminder: Figure 13-24 and Figure 13-25 can be photocopied front to back and used in the field.

14. Abandonment: When to Plug & Seal Wells

Chapter Description

This chapter outlines when the *Wells Regulation* requires that a well be abandoned by the well owner or the person constructing the well. It also provides the steps that a well owner may take to seek written consent from the Director to allow for the continued use of the well. Chapter 15 Abandonment: How to Plug & Seal Wells outlines the sequential approach and materials used to plug and seal a well.

Regulatory Requirements - Abandonment: When To Plug And Seal Wells

Relevant Sections - The *Wells Regulation*

Abandonment - Section 21 (when to abandon a well)

The Requirement - Plainly Stated

The *Wells Regulation* requires a well to be abandoned based on the following:

When to Abandon a Well:

Person Constructing the Well

If construction is completely stopped (i.e., discontinued) before completion of the new well's structural stage and no other person completes the new well to its structural stage, the person constructing the well must immediately abandon the well.

Well Purchaser

The well purchaser of a new well that is dry must immediately abandon the well unless the owner of the land on which the well is situated agrees in writing to maintain the well for future use as a well.

Well Owner

The well owner must immediately abandon a well if it:

- is not being used or maintained for future use as a well,
- produces mineralized water,
- produces water that is not potable (unless the well owner seeks advice of, and follows, the directions of the local medical officer of health),
- contains natural gas or other gas (unless measures are taken by the well owner to manage the gas in a way that prevents any potential hazard),
- permits any movement of natural gas, contaminants or other materials between subsurface formations (aquifers), or between a subsurface formation and the ground surface, and the movement may impair the quality of any waters (unless measures are taken by the well owner that prevent the movement at all times), or
- is constructed in contravention of any provision of the *Wells Regulation* dealing with the location of wells, the methods and materials used in the construction of wells or the standards of well construction, and the steps taken to immediately rectify the situation have failed.

Reminder: In certain circumstances a well owner does not have to abandon a well. See the "Exemption - Well Abandonment of an Agricultural Well", "Seeking Advice from the Local Medical Officer of Health" and "Director's Written Consent not to Abandon a Well" sections in the Plainly Stated of this chapter.

Reminder: The well owner does not have to immediately abandon a test hole or dewatering well if it:

- produces mineralized water, or
- produces water that is not potable.

Reminder: In most cases, the well purchaser or well owner will retain a licensed well contractor and well technician to abandon the well (see Chapter 15: Abandonment: How to Plug & Seal Wells).

Exemption - Well Abandonment of an Agricultural Well

The well owner is not required to abandon the well if the well produces water that is "mineralized water" or not potable under the following scenario:

- the well is used or intended for use as a source of water for agriculture (such as watering livestock or irrigating crops), and
- the well is not used as a source of water for human consumption.

Exemption - Seeking Advice from the Local Medical Officer of Health

For a well that does not meet the above agricultural well scenario, a well owner of a well that is producing water that is not potable may immediately seek the advice of and take such measures as directed by the local medical officer of health instead of immediately abandoning the well.

If the well owner does not contact the medical officer of health or does not follow the measures directed by the local medical officer of health, the well owner must immediately abandon the well.

Director's Written Consent not to Abandon a Well

The well owner is not required to abandon a well if the well owner has sought and obtained the written consent of the Director to allow for the continued use of the well for the following situations:

- a well produces mineralized water,
- a well produces water that is not potable and the well owner does not immediately seek advice from the local medical officer of health or does not follow the directions of the local medical officer of health,
- a well contains natural gas or other gas and the well owner has not taken measures to manage the gas to prevent any potential hazard,
- a well permits any movement of natural gas, contaminants or other materials between subsurface formations (e.g., aquifers), or between a subsurface formation and the ground surface, the movement may impair the quality of any waters and the well owner has not taken measures to prevent the movement, or
- the steps taken by the well owner have failed to rectify a situation where a well has been constructed in contravention of any provision of the *Wells Regulation* dealing with the location of wells, the methods and the materials used in the construction of wells, or standards of well construction.

Relevant Sections - Additional Regulations Or Legistation

Safe Water Drinking Act, S.O. 2002, Chapter 32 - Section 10

Safe Water Drinking Act, S.O. 2002, Chapter 32; *Ontario Regulation 169/03, Ontario Drinking Water Quality Standards*.

Key Concepts

What Is An Improperly Abandoned Well?

An improperly abandoned well is one that has not been plugged and sealed and that is any of the following:

- No longer used or maintained for use as a well
- In such disrepair that its continued use for obtaining groundwater is impractical
- A well that has been left uncompleted

Figure 14-1: Improperly Abandoned Drilled Well

Figure 14-1 shows an example of an improperly abandoned drilled well within a large excavated open hole. The open excavation presents a physical hazard and a pathway for surface water runoff and other contaminants to enter the well water and groundwater resource.

Figure 14-2: Improperly Abandoned Dug Well

Figure 14-2 shows an example of an improperly abandoned dug well with large opening in the well cover. The opening in the well cover presents a physical hazard and a pathway for surface contamination to enter the well water and groundwater resource.

How Many Wells And Abandoned Wells Are There In Ontario?

From the late 1940s, well contractors have been required to report drilled and bored well construction operations to the well owner and the Ontario Government. In the late 1980s, all persons constructing dug wells were required to complete well records. Well records are required to be submitted to the Ministry to document many well construction, alteration or abandonment of wells in Ontario. Over 700,000 well records have been submitted to the Ministry over the years with approximately 15,000 new well records received each year.

At this time no one knows exactly how many wells or abandoned wells exist in the Province of Ontario due to the evolving reporting requirements for wells.

If a well has been reported to the Ministry, a copy of the record can be requested from the Ministry to assist in the plugging and sealing of a well. The well record search request forms are available on the Ontario Central Forms Repository (also by typing "wells" in the search bar) or by contacting the Ministry's Well Help Desk at (toll-free for Ontario residents).

It is important that land owners understand their responsibilities under the *Wells Regulation*. It is important for environmental protection and health and safety reasons that land owners take the time to investigate and identify improperly abandoned wells that may exist on their property. The well construction industry and environmental consultants should assist well owners in identifying improperly abandoned wells when working on a property and inform them of their responsibilities under the *Wells Regulation*.

What Problems Do Improperly Abandoned Wells Present?

Improperly abandoned wells may pose including any or all of the following problems:

- They can act as pathways for the movement of near-surface contaminants into aquifers (groundwater supplies).
- They can pose a threat to children, adults or animals who may fall into large diameter openings and become trapped or injured (Figure 14-3).
- They can interconnect fresh groundwater with salty, mineralized or contaminated groundwater zones and allow the mineralized or contaminated water to enter into fresh water zones.
- They can present a hazard to equipment and vehicles.
- They can flow uncontrollably at the surface resulting in groundwater waste, nuisance or flooding problems (see Figure 14-4).

Figure 14-3: Improperly Abandoned Large Diameter

Figure 14-3 shows a large diameter improperly abandoned well with an open well cover (behind child). This can present a safety hazard for children.

Figure 14-4: Improperly Abandoned Flowing Well

Figure 14-4 shows an improperly abandoned flowing well causing flooding damage and wasting of the groundwater resource.

Merely capping or covering the top of a well is not enough to prevent the well from becoming a problem as shown in Figures 14-1 to 14-4.

To help protect the health and safety of humans and protect the environment, improperly abandoned wells need to be properly plugged and sealed.

How Can I Find Out If Have An Improperly Abandoned Well On My Property?

A person may wish to inspect their property for signs of an existing unused well. Some indicators of unused wells include any of the following:

- pipe sticking out of the ground,
- concrete slab with or without a hand pump,
- ring of rocks or bricks,
- windmill,
- old shed (e.g., pump house),

- wooden slab on the ground,
- depression in the ground, or
- flowing water, or constant wet area on the ground surface

Figure 14-5: Hidden Dug Well

In many cases, brush or debris can hide a well. As shown in Figure 14-5, tall grass and brush hide an open and deteriorated large diameter dug well.

Figure 14-6: Contamination And Safety Risk

In Figure 14-6, the hidden open dug well presents a hazard to humans and easy access for surface water and other foreign materials to enter the groundwater resource.

If there is a possibility that a well is buried below the ground surface, the following sources of information may assist in locating the well:

- Former property owners or neighbours
- Well record reports
- Property surveys
- Old photographs
- Fire insurance plans
- Former septic system plans

Two methods of locating a buried well include:

- a metal detector for wells with steel casing and
- a plumber's video camera equipment and an above ground camera equipment receiver for wells where a horizontal waterline extends from the buried well into a building.

Figure 14-7: Buried Well And Water Lines

Figure 14-7 shows a buried drilled well and waterlines exposed after excavating from the ground surface. Buried wells are difficult to locate and detection devices may be needed. In this case there is no well cap to stop surface water or other foreign materials from entering the well.

Who Is Responsible For Plugging And Sealing Wells

Well owners, well purchasers or persons constructing wells must abandon (plug and seal) a well using the nine (9) sequential step approach (see Chapter 15: Abandonment: How to Plug and Seal Wells) for unfinished wells, certain well construction and maintenance deficiencies, water quantity problems and water quality problems. These requirements are described in the following sections.

Well owners, well purchasers and persons constructing wells are subject to enforcement actions, such as orders and/or prosecution, if abandoned wells are not properly plugged and sealed or if groundwater contamination results.

Well owners may be liable if a person is injured due to an improperly abandoned well on their property.

By eliminating both the physical hazards and contamination pathways, well owners are protecting the water quality of existing and future wells and the groundwater. By taking these precautions, well owners are also reducing potential financial liabilities while making a wise investment in the future.

Reminder: When this chapter refers to the "well owner" or "well purchaser" being required to abandon a well or address a specific issue with the well, it is understood that the person doing the work should have the appropriate expertise. Although the *Wells Regulation* allows a residential well owner to abandon his/her own well without a licence, the equipment, materials and expertise needed to comply with the requirements under the *Wells Regulation* can exceed the average well owner's abilities and resources. If remuneration takes place, or if the land owner is a business corporation, partnership, sole proprietor or a government agency, the land owner must retain a licensed well contractor, or other person allowed by the *Wells Regulation*, to abandon the well. See Chapter 15: Abandonment: How to Plug and Seal Wells.

When Is A Person Constructing A Well Legally Required To Abandon A Well

Discontinued Wells

The *Wells Regulation* - If the construction of a new well has been discontinued prior to the completion of the well's structural stage, the person constructing the well must abandoned (plug and seal) the well (see Chapter 15: Abandonment: How to Plug & Seal Wells).

Definintion - A well's structural stage is complete on the day on which the well is capable of being used for the purpose for which it was constructed, except for any of the following:

- Compliance with disinfection requirements of the *Wells Regulation*,
- The installation of a pump (which includes any associated pumping equipment) or
- Any alteration necessary to accommodate pumping, monitoring, sampling, testing or water treatment equipment.

The person constructing a new well, well owner, and well purchaser should be aware that the construction of a well is not deemed discontinued when the following situations apply:

- The person has completed all of the above except for affixing a well tag, developing a well or conducting a yield test.
- The person cannot finish the new well due to an equipment breakdown or other reason and the well purchaser will retain another person to finish the well within a reasonable time.

If the person constructing a new well does not install an appropriate device that is capable of controlling the flow of water from a flowing well as required by the *Wells Regulation*, then the well is deemed unfinished and must be properly abandoned by the person constructing the well.

If the device does not meet the *Wells Regulation* requirements, or if the well acts as a pathway for materials that may impair the quality of any waters, then the well owner also shares responsibility for the well abandonment.

Reminder: For more information on flowing wells and costs associated with controlling the flow, see Chapter 12: Flowing Wells

When Are Well Purchasers Legally Required To Abandon A Well

The *Wells Regulation* requires a well purchaser to immediately abandon (plug and seal) a new well that is dry (see Chapter 15: Abandonment: How to Plug & Seal Wells).

The *Wells Regulation* - A well purchaser is exempt from this abandonment requirement if the owner of the land on which the well is situated agrees in writing to properly maintain the well for future use as a well. For example, a well that may be dry at the time of construction may, after a few days or weeks, slowly yield groundwater.

Definition - A well purchaser is a person who has entered into a contract for the construction of a well with a person who is engaged in the business of well construction (well contractor).

Reminder: Proper maintenance involves preventing the entry of surface water and other foreign materials into the well.

When Are Well Owners Legally Responsible To Abandon A Well

Well owner
: means the owner of land upon which a well is situated and includes a tenant or lessee of the land and a well purchaser.

A) Maintenance

The *Wells Regulation* requires a well owner to immediately abandon (plug and seal) a well that is not being used or maintained for future use as a well (see Chapter 15: Abandonment: How to Plug & Seal Wells).

For example:
A municipal water distribution system has been installed in a number of residences that originally relied on private wells. Unless there is a reasonable chance that the wells will be used and the wells are maintained in a manner sufficient to prevent the entry of surface water and other foreign materials, the well owners would be required to immediately abandon the wells.

B) Mineralized Water

The *Wells Regulation* requires a well owner to immediately abandon (plug and seal) a well that produces mineralized water (see Chapter 15: Abandonment: How to Plug & Seal Wells).

Definition - The *Wells Regulation* considers the well water to be "mineralized water" when well water contains concentrations of chlorides or sulphates at more than 500 mg/L or total dissolved solids at concentrations of more than 6,000 mg/L.

For example:
A well owner operates a private domestic well. The well has a salty taste. The well owner submits samples of raw well water to a licensed laboratory. The sample determinations show chloride concentrations significantly above 500 mg/L. In this instance the well is producing mineralized water as defined in the *Wells Regulation* and the well owner would be required to immediately abandon the well.

Exemptions

The requirement to abandon a well producing "mineralized water" does not apply where:

- the well is used or intended for agricultural purposes such as watering livestock or crops and that is not used as a source of water for human consumption,
- the well defined as a test hole or dewatering well, or
- where the Director has provided a written consent not to abandon the well producing mineralized water (see the "Director's Exemption for Well Owners" section in this chapter).

C) Not Potable Water

The *Safe Drinking Water Act, 2002*, requires "potable water" to meet at least the standards prescribed in the Ontario Drinking Water Quality Standards (*Ontario Regulation 169/03* as amended, under the *Safe Drinking Water Act, 2002*).

The *Wells Regulation* requires a well owner to immediately abandon (plug and seal) a well (see Chapter 15: Abandonment: How to Plug & Seal Wells).if the well produces water that is not potable (i.e., does not meet one or more of the standards found in the Ontario Drinking Water Quality Standards).

Abandonment is not required if the well owner seeks the advice of, and take such measures as directed by, the local medical officer of health (see the "Seeking Advice from the Local Medical Officer of Health" section in this chapter).

For example:
A well owner operates a private domestic well used for human consumption. The well owner submits samples of raw well water to a licensed laboratory for bacterial analyses. The sample determinations show the presence of Escherichia coli (E.coli) in the well water. In this instance the well is producing water that is not potable. The well owner would be required to do one of the following:

- immediately abandon the well, or
- seek the advice of, and take such measures as directed by, the local medical officer of health (see the "Seeking Advice from the Local Medical Officer of Health" section in this chapter).

The measures specified by the local medical officer of health, such as the installation and use of water treatment devices, must be functional at all times.

Exemptions

The requirement to abandon a well producing water that is not potable does not apply where:

- the well is used or intended for agricultural purposes such as watering livestock or crops and that are not used as sources of water for human consumption,
- the well is defined as a test hole or dewatering well, or
- the Director has provided a written consent not to abandon the well producing water that is not potable (see the: "Director's Exemption for Well Owners" section in this chapter).

D) Natural Gas

The *Wells Regulation* requires a well owner to immediately abandon (plug and seal) a well that contains natural gas or other gas (see Chapter 15: Abandonment: How to Plug & Seal Wells).

Abandonment is not required if the well owner takes measures to manage the gas in a way that prevents any potential hazard.

For example:
A well owner operates a private domestic well used for human consumption. It has been established through testing and observations that naturally occurring methane gas from the well water is entering the home and is posing an explosion risk. In this instance, there would be enough information to conclude the well is producing naturally occurring gas. The well owner would be required to do one of the following:

- immediately abandon the well, or
- take measures to manage the gas in a way that prevents any potential hazard.

The measures taken to manage the gas must be functional at all times.

Exemptions

The requirement to abandon a well producing naturally occurring or other gas(es) does not apply where the Director has provided a written consent not to abandon the well producing the gas (see the “Director’s Exemption for Well Owners” section of this chapter).

E) Wells Acting As Pathways

The *Wells Regulation* - If a well permits the movement of:

- natural gas,
- contaminants, or
- other materials

between subsurface formations (including aquifers) or between the ground surface and a subsurface formation and the movement may impair the quality of the waters, the *Wells Regulation* requires a well owner to immediately abandon (plug and seal) a well (see Chapter 15: Abandonment: How to Plug & Seal Wells).

Abandonment is not required if the well owner takes measures to prevent the movement of the natural gas, contaminants or other materials at all times.

For example:

a. A flowing well is discharging groundwater with elevated uranium into a nearby cold water creek. The elevated uranium may impair the surface water of the creek.
b. Surface water runoff containing bacteria is flowing on the ground surface through an open hole in the casing of a well. The surface water runoff containing bacteria may impair the water in the well and aquifer.

In both instances there would be enough information to conclude the well is acting as a pathway that may impair the waters. The well owner would be required to do one of the following:

- immediately abandon the well, or
- take measures to prevent any movement at all times.

The measures taken must be functional at all times.

Exemptions

The requirement to abandon a well that acts as a pathway does not apply where the Director has provided a written consent not to abandon the well (see the “Director’s Exemption for Well Owners” section in this chapter).

F) Wells In Contravention Of The *Wells Regulation*

The *Wells Regulation* - If a well is constructed in contravention of any provision of the *Wells Regulation* dealing with the location of wells, the methods and materials used in the construction of wells or the standards of well construction, the well owner must immediately take steps to rectify the situation but if those steps fail, the well owner must immediately abandon (plug and seal) the well (see Chapter 15: Abandonment: How to Plug & Seal Wells).

For example:

a. An improper well location may be a drilled well located within 15 metres (50 ft) of a septic tank and leaching bed system or may be a well located in a low lying ditch.

b. An improper method used in the construction of a well may be installing bentonite or concrete in the annular space of a drilled well from the ground surface without the aid of a tremie pipe.
c. An improper method may be the top of the casing of a new drilled well is 30 cm instead of a minimum of 40 cm above the ground surface
d. An improper material used in the construction of a well may be the installation of permeable sand in the annular space of a well that allows for the movement of a contaminant from the ground surface to an aquifer.
e. An improper material may be an improper device to control the flow has been installed on a flowing well.
f. An improper standard of well construction may be the use of steel well casing in a drilled well that does not meet the nominal and minimum thickness required by the *Wells Regulation* or the casing does not meet ASTM International standards specified by the *Wells Regulation*.

In these examples, the well has not been constructed to the required minimum standards, methods and materials, and creates a potential for the well to act as a pathway to enter groundwater or the well. Due to the contraventions, the well owner would be required to immediately do the following:

- take steps to rectify the problem; but
- if the steps fail, abandon the well.

In other scenarios, a case by case evaluation may be required to determine whether a violation of the *Wells Regulation* triggers a well to be abandoned by the well owner.

Examples of contraventions of the *Wells Regulation* requirements that would not require the well owner to immediately take measures, and if necessary, abandon the well are:

- improper well record completion or reporting,
- failure to provide written records of the testing during disinfection,
- lack of a well tag on the well or improperly affixing the well tag,
- improper yield tests,
- failure to properly notify the well purchaser and the owner of the land of water quality issues or gas, or
- failure to provide the well purchaser with a well information package or to measure the depth of the well in the presence of the well purchaser.

Reminder: Even though the above noted types of contraventions are exempted from the requirement to immediately take measures to rectify the problem, and if necessary abandon the well, these contraventions are, however, subject to enforcement actions (e.g., orders, fines).

Exemptions

The requirement to immediately take measures to rectify a well that is in contravention of a requirement in the *Wells Regulation* does not apply to the well owner where the Director has provided written consent (see the “Director’s Exemptions for Well Owners” section in this chapter).

The requirement to immediately abandon a well, if the measures taken to rectify the contravention fail, does not apply where the Director has provided written consent (see the “Director’s Exemption for Well Owners” section in this chapter).

Director's Exemptions For Well Owners

When Can A Well Owner Seek An Exemption?

The *Wells Regulation* - The well owner is not required to abandon a well if the well owner has sought and obtained the written consent of the Director to allow for the continued use of the well for any of the following situations:

- A well produces mineralized water,
- A well produces water that is not potable and the well owner does not immediately seek advice from the local medical officer of health or does not follow the directions of the local medical officer of health,
- A well contains natural gas or other gas(es) and the well owner has not taken measures to manage the gas to prevent any potential hazard,
- A well permits any movement of natural gas, contaminants, or other materials between subsurface formations, or between a subsurface formation and the ground surface, the movement may impair the quality of any waters and the well owner has not taken measures to prevent the movement, or
- A well is constructed in contravention of any provision of the *Wells Regulation* dealing with the:
    - Location of wells,
    - Methods and materials used in the construction of wells, or

- Standards of well construction
- and the steps taken to immediately rectify the situation have failed.

Where Does The Well Owner Have To Go To Seek A Written Consent From The Director?

If a well owner wishes to seek the written consent of the Director, the well owner may contact the Wells Help Desk:

- In writing to Wells Help Desk, Environmental Monitoring and Reporting Branch of the Ministry of the Environment and Climate Change, 125 Resources Road, Toronto ON M9P 3V6,
- By fax at: 416-235-5960, or
- By e-mail at helpdesk@waterwellontario.ca

What Information Is Needed For A Written Consent?

The Director reviews each case individually and on its merits. As a minimum, applicants contacting the Ministry for a written consent should provide a written request with the following information:

- The name of the individual(s)/entity that owns the well
- The location of the well
- Whether the well is new or an existing well
- The purpose of the well
- The reason for the exemption (e.g., contaminant(s) of concern encountered, contravention of the *Wells Regulation*)
- Historical and current water quality information
- If applicable, justification as to why the well does not need to be immediately abandoned (e.g., well can be allowed to stay in contravention of the *Wells Regulation* if temporary measures are in place to eliminate physical hazards and protect the groundwater until a final rectification occurs, etc.)

If there are well design issues or gas issues, a well owner may be required by the Director to retain a Professional Engineer or Professional Geoscientist to prepare a scientific report showing the appropriate scientific rationale to support the well owner's application. The well owner would then submit the report, along with the request for written consent, to the Ministry for consideration.

Well owners and others should be cautioned that obtaining a written consent will not be an automatic process, since the Ministry has to provide for the conservation, protection and management of Ontario's waters and for their efficient and sustainable use, to promote Ontario's long-term environmental, social and economic well-being.

The Director will review the request, supporting information, and other information generated from internal and external parties with an interest in the application.

Based on the information, the Ministry will contact the well owner in writing indicating the Director's decision.

Seeking Advice From The Local Medical Officer Of Health

Medical Officer Of Health Exemption From Abandonment For A Well Producing Water That Is Not Potable

How To Find The Local Medical Officer Of Health

There are 36 public health units in Ontario. A public health unit is governed by a board of health and is administered by the medical officer of health who reports to the local board of health.

To determine which local public health unit in Ontario covers an area, do any of the following:

- Call ,
- Review the blue pages of the telephone book, or
- Check the information at the Ministry of Health and Long-Term Care website.

When Should The Public Health Unit (Local Medical Officer Of Health) Be Contacted?

Potable means water that meets the Ontario Drinking Water Quality Standards found in *Regulation 169/03* as amended made under the *Safe Drinking Water Act, 2002*.

When a well produces well water that is not potable (i.e., does not meet one or more of the Ontario Drinking Water Quality Standards), the well owner may seek the advice of and take such measures directed by the local medical officer of health as an alternative to

immediately abandoning the well.

This requirement applies to all wells except those wells that are used or intended for use as a source of water for agriculture and are not used as a source of water for human consumption.

What Kind Of Advice And Direction Will Be Given By The Public Health Unit?

The Memorandum of Understanding between the Ministry of the Environment and the Ministry of Health and Long-Term Care Pertaining to Drinking Water, Revision Date: March 1, 2013, provides the roles and responsibilities of the local public health unit and the local office of the Ministry of the Environment and Climate Change for wells that produce water that is not potable.

If there is a water quality concern in a private domestic well with water that is not potable, a local public health unit representative will respond to the issue, provide assistance in the interpretation of the water analysis report, provide information on potential health effects and offer any other advice and direction.

If the well is part of a regulated system under the *Safe Drinking Water Act*, or a small drinking water system under the *Health Protection and Promotion Act*, the local office of the Ministry of the Environment and Climate Change and the public health unit will use the MOU in responding to notifications of well water that is not potable, in providing direction to the well owner and in communicating the action taken between the public health unit and the local office of the Ministry of the Environment and Climate Change to resolve the issue.

The MOU also allows the public health unit to seek assistance from the local office of the Ministry of the Environment and Climate Change in certain cases (e.g., to identify sources of contamination).

What Happens After Direction Has Been Given By The Public Health Unit?

The *Wells Regulation* requires that, once measures have been taken to rectify a well that is producing water that is not potable problem (such as the installation of water treatment devices) under the direction of the local medical officer of health, the well owner must ensure that the measures remain functional at all times.

Reports of failure to follow the advice and direction of the local public health unit (local medical officer of health) are to be referred to the local office of the Ministry of the Environment and Climate Change.

15. Abandonment: How to Plug & Seal Wells

Chapter Description

This chapter covers the step-by-step process involved in abandoning a well as required by the *Wells Regulation*. This chapter outlines the sequential approach and materials used to plug and seal a well.

Regulatory Requirements - Abandonment: How To Plug And Seal Wells

Relevant Sections - The *Wells Regulation*

Abandonment – Subsection 21(13) and Section 21.1 (How to abandon a well)

The Requirements - Plainly Stated

The person abandoning the well is considered:

In the case of a well that must be immediately abandoned, the person abandoning the well is one of the following:

- the person who has discontinued the construction of a new well prior to the completion of its structural stage
- the well purchaser of a new well that is dry
- the well owner of a well that:
    - is not in use or being maintained for future use as a well,
    - is producing water that is mineralized or not potable (not applicable to test holes or dewatering wells),
    - contains natural gas or other gas,

- permits the movement of materials including natural gas and contaminants and the movement may impair the quality of the waters, or
- is constructed in contravention of the *Wells Regulation* requirements for location, methods, materials or standards and measures taken to rectify the problem have failed.

Abandonment of a well is not considered well construction. As a result, licensing requirements for the construction of a well do not apply to well abandonment and the obligations for abandonment are placed on the person abandoning the well, often the well owner.

Obligation to Retain a Licensed Well Contractor

Unless exempted by the *Wells Regulation*, the person abandoning the well, often the well owner, must do the following:

- retain the services of a licensed well contractor, and
- ensure the contract with the well contractor contains a provision that the well technician who will do the abandonment work, is licensed to construct the same type of well as the one to be abandoned.

Exemption - Obligation to Retain a Licensed Well Contractor

The person abandoning the well is exempt from the above requirements if the person who works at the abandonment of the well is:

- the owner of the land or is a member of the owner's household,
- working without remuneration (e.g., not being paid) for another person on land owned by the other person or on land owned by a member of the other person's household, or
- a person who holds a Class 1 well technician licence (drilling).

How To Abandon A Well

The person abandoning the well must ensure the following nine (9) steps are taken in this sequence, unless otherwise specified:

1. If the well has a well tag, it must be removed and returned to the Director within 30 days of its removal.
2. If the well casing or well screen has collapsed, reasonable efforts must be made to remove the well screen or well casing. All other equipment and debris in the well must be removed.

3. The well, including any annular space, must be plugged in the following manner:

   For Any Well:

   Abandonment barrier material must be placed continuously from the bottom of the well upward to approximately 2 m (6.6ft) below the ground surface. This does not prevent the placement of clean, washed sand or gravel adjacent to water producing zones or bedrock fractures to minimize the loss of abandonment barrier (sealant) material.

   The abandonment barrier must be placed in a manner that prevents any movement of water, natural gas, contaminants or other material between subsurface formations (which include aquifers) or between a subsurface formation and the top of the abandonment barrier material.

   An Alternative Method For Wells with a Diameter ≥ 65.0 centimetres (≥ 2.1 ft):

   A continuous column of abandonment barrier must be placed up to approximately 2 metres (6.6ft) below the ground surface as follows:

   - Clean sand or pea gravel must be placed from the bottom of the well to the top of the deepest water producing zone or the top of the well screen, whichever is deeper
   - At least 0.1 m (4 inches) of bentonite chips or pellets must be placed over the sand or pea gravel
   - If the water level is below, or can be drawn down to the top of the bentonite chips or pellets:
     - it must be drawn down to the top of the bentonite chips or pellets,
     - at least 0.3 m (1 ft) of a bentonite slurry that consists of clean water and at least 20% bentonite solids and that is compatible with the quality of the water found in the well must be placed over the bentonite chips or pellets, and
     - clean gravel, sand, silt or clay must be dropped over the bentonite slurry to fill the remainder of the well, while maintaining at least 0.3 m of the bentonite slurry above the rising accumulation of gravel, sand, silt or clay.

- If the water level cannot be drawn down to the top of the bentonite chips or pellets, the remainder of the well must be filled to approximately 2 metres (6.6ft) below the ground surface with an abandonment barrier, which may be interspersed (layered) with clean sand or pea gravel placed in each water producing zone of the well.

  The sealing materials that are selected and placed must provide the appropriate structural strength to support the weight of persons and vehicles that may move over the area after it is filled.

4. After or during the placement of the abandonment barrier, the well casing or well screen must be removed, if reasonably possible. During the removal of the well screen or well casing, the bottom of the casing must be immersed in the rising accumulation of the abandonment barrier material until the required level has been reached.
5. If all of the casing and well screen cannot be reasonably removed as above, then at least 2 metres (6.6ft) of casing below the ground surface must be removed if reasonably possible
6. If the abandonment barrier contains cement, it must set until firm and, if necessary, it must be topped up to approximately 2 m (6.6ft) below the ground surface.
7. At any time before sealing the well to the ground surface (step 8), any below ground concrete structures, foundations, and slabs must be removed unless the removal may cause the remaining structures to become destabilized, damaged or unsafe. The structures have to be removed to a depth adequate to accommodate the sealing measures described below in step 8.
8. To prevent inadvertent or unauthorized access, the well and the well opening (including any excavation) must be sealed up to the ground surface by placing:
   - 50 cm (20 inches) to 150 cm (59 inches) of bentonite chips, pellets, granules or powder in accordance with the manufacturer's specifications; and
   - soil cover, or other material that is more in keeping with the material immediately adjacent to the well opening, over the bentonite and up to the ground surface to prevent inadvertent and unauthorized access.
9. The disturbed area must be stabilized to prevent erosion.

Abandonment Barrier

Abandonment Barrier - General

The abandonment barrier must:

- be compatible with the quality of the water found in the well,
- not contain any materials that may impair the integrity of the abandonment barrier, including soil or drill cuttings, and
- be stable in the presence of any contaminants, if the well is in contact with contaminants

Abandonment Barrier - Wells ≤ 6.5 cm (2.5 inches) in Diameter

If the well casing and well screen have been removed or are being removed, the abandonment barrier must be a slurry consisting of:

- clean water, Portland cement and not more than 5% bentonite solids by weight, or
- clean water and at least 20% bentonite solids by weight, and the abandonment barrier must be placed using a tremie pipe, with the bottom of the tremie pipe immersed in the rising accumulation of the abandonment barrier until the required level has been reached.

The above also applies, with necessary modifications, to an uncased well that is less than or equal to 6.5 cm (2.5 inches) in diameter.

If the well casing and well screen have not been removed, the abandonment barrier must be:

- a slurry consisting of clean water, Portland cement and not more than 5% bentonite solids by weight, or
- bentonite chips or pellets that have been screened and placed in accordance with the manufacturer's specifications.

Abandonment Barrier - Wells ≥ 6.5 cm (2.5 inches) in Diameter

The abandonment barrier must be:

- a slurry consisting of clean water and at least 20% bentonite solids by weight,
- a slurry consisting of clean water, Portland cement and not more than 5% bentonite,
- a slurry consisting of clean water and Portland cement,
- a slurry consisting of clean water, Portland cement and clean sand,
- a slurry consisting of equal weights of Portland cement and clean gravel, mixed with clean water,
- a slurry (sometimes called a concrete slurry) consisting of clean water, Portland cement, clean sand and clean gravel,

- bentonite chips or pellets that have been screened and placed in accordance with the manufacturer's specifications, or
- other material approved in writing by the Director, if the Director is of the opinion that the performance of the other material is the equivalent of the performance of a slurry referred to above.

A wet abandonment barrier for a well that has a diameter of greater than 6.5 cm (2.5 inches) must be placed using a tremie pipe, with the bottom of the tremie pipe immersed in the rising accumulation of the abandonment barrier until the required level has been reached.

Alternative Abandonment Barrier - Wells ≥ 65 centimetres (2.1 ft) in Diameter:

See the alternate abandonment barrier material and method previously described in step 3 of "How to Abandon a Well" in the Plainly Stated section.

Abandonment of Flowing Wells:

If the well is a flowing well, commercially manufactured drilling mud that does not impair the quality of the water with which it comes in contact may be used, in taking the steps required above to assist with drilling or placement of an abandonment barrier, but the drilling mud may not be used as an abandonment barrier.

Well Pits:

A well pit must be abandoned like a well, with necessary modifications.

Overdrilling

Requirements for the removal of well casing and well screen in sequence (i.e., steps 2, 4 and 5 above) do not apply if a person overdrills (reams) the entire well before filling the well with abandonment barrier.

Reminder: If the entire well is over drilled, the entire well including the casing and well screen will be removed, allowing for the proper placement of the abandonment barrier.

Excavation of Entire Well

Except for step 1 (referring to well tags) the above plugging and sealing requirements do not apply when a person abandons a well by excavation of the entire well in the course of work carried out for another purpose (e.g., construction of a foundation).

Reminder: A person can abandon a well before it is completely excavated. In this case, the person abandoning the well, often the well owner, must ensure that:

- the "Obligation to Retain a Licensed Well Contractor" or the "Exemption - Obligation to Retain a Licensed Well Contractor" sections in Chapter 3: Well Contractors & Well Technicians – Licences, Responsibilities & Exemptions are followed,
- the well is abandoned following the nine sequential step approach described in this chapter, and
- unless exempt, a well record is completed and submitted as described in Chapter 13: Well Records, Documentation, Reporting & Tagging

Reminder: For further information on circumstances where excavating an entire well may be appropriate, see the "Excavating the Entire Well" section in this chapter.

Relevant Sections - Additional Regulations Or Legislation

Ontario Regulations 164/99: Electrical Safety Code as amended made under the *Electricity Act, 1998*. S.O. 1998. Chapter 15, Schedule A

Ontario Regulation 632/05 (Confined Spaces) as amended made under the *Occupational Health and Safety Act*, R.S.O. 1990, Chapter 0.1

Relevant Guidance Documents

Fleming College. 2008. Manual for Continuing Education Course Safety (for Ontario Well Technicians).

Key Concepts

The well abandonment process can vary depending on multiple factors including the diameter of a well, the well casing, the environment, and the condition of the well.

Initial Considerations

Prior to plugging a well, a person should review background records, including well records and hydrogeological reports, and conduct a site assessment.

Another initial factor to consider is who will be plugging and sealing the well. Regardless of who abandons the well, the requirements of the *Wells Regulation* must always be met.

Common Types Of Wells Encountered

This chapter discusses well abandonment as it applies to:

- Narrow diameter wells less than or equal to 6.5 cm (2.5 inches), typically diamond drilled or point wells
- Medium diameter wells greater than 6.5 cm (2.5 inches) and less than or equal to 65 cm (2.1ft) typically drilled wells
- Large diameter wells over 65 cm (2.1ft), typically dug or bored wells

Table 15-1: Examples Of Typical Types Of Narrow, Medium And Large Diameter Wells Encountered

Characteristic	**Narrow Diameter Wells**	**Medium Diameter Wells**	**Large Diameter Wells**
Hole Diameter (includes casing plus filled annular space)	• ≤ 6.5 cm (2.5 inches)	• ≥ 6.5 cm and ≤ 65 cm (≥ 2.5 inches and ≤25 inches)	• ≥ 65 cm (2.1ft)
Depth	• Point: ≤ 9 m (30ft) • Direct push: ≤ 46 m (150ft) • Diamond drilled: ≥ 9 m (30ft)	• Drilled: ≥ 9 m (30ft) • Direct push: ≤ 46 m (150ft) • Sonic: ≤ 244 m (800ft) • Hollow-stem auger: ≤ 61 m (200ft) • Continuous flight aurger: ≤ 31 m (100ft)	• Dug: ≤ 9 m (30ft) • Hollow-stem auger: ≤ 61 m (200ft) • Continuous flight auger: ≤ 31 m (100ft) • Bucket(bored): ≤ 31 m (100ft)
Well Screen	• Overburden: Likely • Bedrock: possible	• Overburden: Likely • Bedrock: possible	• Possible
Casing Material	• Steel, stainless steel, aluminium, plastic or fibreglass	• Steel, stainless steel, plastic or fibreglass	• Concrete, steel, galvanized steel, fibreglass or plastic
Construction Method	• Point: driven and/or possibly jetted • Direct push • Diamond drilled: typically air track rotary	• Rotary or cable tool • Sonic • Direct push • Continuous flight and hollow-stem augers	• Dug: backhoe, highhoe, other excavating machine or by hand • Auger • Bucket
Annular Seal where well is cased	• Point: possible • Diamond drilled: possible	• Possible	• Possible depending on age

Reminder: Table 15-1 does not represent all possible situations due to changing technology, variation in construction techniques and changes in regulatory requirements.

Reminder: Well pits and narrow diameter wells extending out of the bottom of large diameter wells are discussed further in this chapter.

Reminder: See definition of "Well Screen" in Chapter 2: Definitions & Clarifications, Table 2-1

Photographs Of Common Wells

Figure 15-1: Typical Driven Point Well Screen Placed In Driven Point Well

Figure 15-2: Typical Dug Well

A typical dug well with circular concrete tiles supporting the sides of the well and the well cover.

Figure 15-3: Older Hand Dug Well

Inside view of older hand dug well with hand lain stone supporting the sides of the well.

Figure 15-4: Typical Drilled Well

A typical drilled well with steel casing extending out of the ground with a vermin-proof well cap

Figure 15-5: Drilled Well in a Well Pit

Inside view of an older drilled well housed below ground surface in a large well pit. In this case, contaminated water is entering the pit, moving through top of the well and contaminating the well water and groundwater.

Types of Filling Materials and Abandonment Barriers

It is necessary to use plugging materials that will ensure proper sealing of the well. The choice of plugging materials is important to:

- ensure the abandoned well does not act as preferential pathway for water, gas or foreign materials between:
  - groundwater zones,
  - between groundwater and the ground surface,
- provide the best overall strength to the abandoned well to support the weight of persons, animals and vehicles,
- provide sufficient viscosity to minimize leakage of the plugging material out of the well and into the groundwater resource or formation, and
- provide the best adhesion of the plugging material to the casing, soil or bedrock to achieve a good seal.

The type of materials selected will depend on the:

- location (e.g., hazards, access restrictions),
- environment (e.g., flowing conditions, presence or absence of contaminants or natural gases, chemistry of the water),
- type of well,
- diameter and depth of the well,
- condition of the well (e.g., damage to the well structure, collapsed casing equipment/debris caught in the well), and
- requirements of the *Wells Regulation*

There are a variety of materials used to plug a well. Plugging materials are made up of:

- abandonment barriers (e.g., concrete, neat cement and sodium bentonite) to prevent the creation of preferential pathways,
- filling materials which include:
  - clean, washed sand or gravel placed in large voids, fracture areas or adjacent to water producing zones to:
    - support abandonment barrier,

    - prevent leakage of the abandonment barrier into the groundwater resource or formation, and
    - restore subsurface conditions at the well site, and
  - clean gravel, sand, silt or clay placed in large diameter wells [≥ 65 cm (2.1ft)] to reduce the quantity of abandonment barrier required to seal the well and to provide increased bearing strength.

Field Notes and Well Records

During the process of well abandonment, the person abandoning a well is required to make and have available at the well site field notes that include an up-to-date record of the abandonment activities.

A well record documenting the abandonment of the well must be completed by the person abandoning the well, often the well owner, and submitted to the owner of the land on which the well is located and the Ministry (see Chapter 13: Well Records, Documentation, Reporting & Tagging).

How to Abandon a Well

The steps involved in the abandonment of a well are as follows:

Initial Procedures

1. Obtaining and Reviewing Relevant Records and Conducting a Site Assessment
2. Determining Expertise Required
3. Selecting Plugging Materials
4. Estimating Plugging Material Volumes Required
5. Preparing Equipment, Selecting Methods and Obtaining Approvals Needed to Plug the Well
6. Determining if Overdrilling is a Best Management Practice

Nine Sequential Step Procedures to Plug and Seal a Well

1. Safeguarding and Returning the Well Tag
2. Removing Equipment, Structures, Debris and Any Collapsed or Broken Well Casing or Well Screen
3. Plugging and Sealing Within 2 Metres (6.6 Feet) of the Ground Surface
4. Removing Entire Casing and Well Screen During Sealing
5. Removing Casing
6. Using Cement or Concrete
7. Removing Below Ground Concrete Structures and Slabs
8. Plugging and Sealing of Upper 2 Metres (6.6 Feet) of the Well Opening
9. Stabilizing Disturbed Area

After the Well is Plugged and Sealed

1. Completing and Submitting a Well Record
2. Providing Important Information to the Well Owner

Initial Procedures

1) Obtaining and Reviewing Relevant Records and Conducting a Site Assessment

Persons plugging a well can use the well record information along with a site assessment of the well to determine the method and materials needed before commencing to plug and seal a well.

To obtain relevant information on the well to be abandoned, a person should consider if there are any historical records of the well.

For example, a well contractor may have completed a well record and log for the original construction of the well. A copy of the original well record may be available from the:

- current or previous land owner,
- original well contractor, or
- Ministry of the Environment and Climate Change.

Well records provide valuable information including the:

- depth and diameter(s) of the well,
- overburden and bedrock encountered during construction,
- depth where groundwater was found,
- depth to static water level in the well,
- general water quality information (e.g., salty, sulphurous),
- presence of naturally occurring gases (e.g., methane, hydrogen sulphide),
- construction materials used in the well (e.g., casing, screen), and
- general location of the well (e.g., UTM, co-ordinates, township or municipality information, map).

In some cases original well records may not be available for the well.

Another example of relevant source of information is hydrogeological reports. Hydrogeological reports can be prepared as a result of various activities including:

- phase 2 environmental site assessments,
- work related to the delineation clean-up, monitoring and clean-up of contaminants, and
- hydrogeological investigations for water supplies.

The reports may provide technical information and mapped locations of wells. These reports may be found at the local:

- Ministry of the Environment and Climate Change office
- Municipality
- Conservation authority

Best Management Practice – Assessing the Well

An assessment of a well should be conducted prior to plugging and sealing it. The assessment should include the following factors: the well depth, the water level, the geochemistry of the well water, the pumping or other equipment in or around the well, the structure of the well and the geological formations around the well. The use of video technology by trained professionals should be included in deep wells to visually confirm the well's characteristics and current conditions

Reminder: There are many serious dangers that must be considered when assessing and working on abandoned wells. Some dangers include the following:

- When inspecting a well, the power supply to the pump or any monitoring equipment should be shut off to minimize the risk of shock or electrocution.
- Many older wells especially dug wells have structural integrity problems and could collapse. As such, it is important to wear appropriate safety gear and to guard against falling into the well. Falling into the well could result in serious injury or death.
- An abandoned well could contain contamination or explosive or poisonous gases that could affect a person's health and safety. As such, it is important to use proper field detection equipment and personal protective gear.

Reminder: It is important that no person enter any confined space unless the person is properly trained in confined space entry and is properly equipped. Confined spaces are non-ventilated areas including a well pit, a pump house, and other areas defined in the *Ontario Regulation 632/05* as amended made under the *Occupational Health and Safety Act* [1] . Confined spaces present asphyxiation hazards and some wells produce naturally occurring gases that may be poisonous and/or explosive.

Visual Assessments

Figure 15-6: Video Technology Used Within A Drilled Well

Figure 15-6 shows a still shot from a video of the open hole portion of a drilled well in bedrock. The hole has a large crevasse, which could not be observed from land surface. With this video information, the contractor can more accurately calculate the amount of plugging material needed and select the best method and equipment to seal the hole.

Figure 15-7: Video Camera And Cable

In Figure 15-7 the video camera and cable are about to be installed in an drilled well.

Figure 15-8: Video Displaying A Well's Interior

In Figure 15-8 the orange and white (mottled) areas shown on the video display indicate that the well water has a significant organic biofilm problem. Therefore, the well will need to be cleaned out and treated prior to plugging to reduce the chance of microorganisms moving from the well and impairing the groundwater resource.

Figure 15-9: Encrusted Metal Screen

Figure 15-9 shows another example of a video display of a well's interior. In this example, the stainless steel well screen at the bottom of a well is plugged with a biofilm. The person who works at the abandonment of the well needs to remove the screen to ensure the filling material will properly allow for the return of the natural groundwater flow at the well site and the biofilm will not react with the filling materials or abandonment barrier.

Best Management Practice – Conducting On-site or Laboratory Testing and Analysis of Well Water

It is important to conduct on-site or laboratory testing and analysis of the well water to further understand the hydrogeological environment around the well and to determine if the well water may react with the plugging materials or abandonment barriers. See Table 15-3 in this chapter for a description of abandonment barriers. A Professional Engineer or Professional Geoscientist may be needed to interpret the laboratory or field results.

2) Determining Expertise Required

Another initial factor to consider is who will be abandoning (plugging and sealing) the well. Regardless of who abandons the well, the requirements of the *Wells Regulation* must always be met.

If a well owner is a corporation or municipality, the well owner must retain the services of a licensed well contractor who employs properly licensed well technicians to work on the well abandonment unless exempt. In some cases the corporation or municipality can use a person who holds a Class 1 well technician (drilling) licence to abandon a well.

An individual land owner or his/her family members can abandon any well situated on his/her own property without a well technician licence. Also, other individuals can abandon a well without a well technician licence for the individual land owner as long as no form of compensation is made.

Although the *Ontario Water Resources Act* and the *Wells Regulation* allow an individual well owner to abandon his/her own well without a licence, the equipment, materials and expertise needed to comply with the requirements under the *Wells Regulation* can exceed the average land owner's abilities and resources. A well owner needs to understand how to measure water levels, well depths and be able to calculate volumes of well water, chemical mixtures and material mixtures. For instance, if an individual land owner cannot properly calculate and mix chemicals, does not have the necessary equipment, or cannot employ proper safety procedures, the requirements of the *Wells Regulation* will not likely be met. An improperly abandoned well could pose a safety or environmental hazard and the well owner may be subject to compliance or enforcement actions.

For further information, licensing requirements are detailed in Chapter 4: Well Contractors & Well Technicians – Licences, Responsibilities & Exemptions. Contact numbers for the Ministry are also listed in the Resources section of this manual.

Best Management Practice – Retain Licensed Well Contractor and, if Necessary, Qualified Persons

Because of the need for specialized equipment and technical skill, which may be beyond the capabilities of an individual well owner, it is important that wells with one or more complicating factors be plugged by a licensed well contractor who employs licensed well technicians. It may also be advisable that Professional Geoscientists or Professional Engineers be retained. Complicating factors include:

- Freely flowing artesian wells where groundwater is discharging from the well at or close to ground surface
- Flowing, heaving and/or running formations (e.g., sands or gravels) are encountered
- Wells greater than 9 metres (30 feet) deep
- Underground crevices in karstic formations

- Wells where surface water runoff, insects or other vermin are entering the well through the well casing
- Wells which produce poisonous or explosive gas, salty or sulphate-rich water
- Wells with well water that may be impacted by on or off-site contaminants (e.g., gasoline, fuel oil, pesticides or agricultural activities)
- Wells where the casing has collapsed or the casing is difficult or not reasonably possible to remove without proper equipment
- Wells where the pumping equipment is difficult to remove
- Wells located in residential, agricultural, commercial or industrial buildings (occupied or vacant)
- Wells located in close proximity to other operating wells
- Wells located in close proximity to surface water
- Improperly Abandoned wells (e.g., plugged with logs or other materials)

Reminder: There may be additional conditions, other than the above list, that suggest that the well be plugged and sealed by licensed professionals.

In some cases, driven and shallow dug wells can be plugged by land owners with a minimal amount of special equipment. However, land owners who improperly abandon (plug and seal) wells may face enforcement actions and additional legal liabilities (e.g., property and environmental damage, personal injury). Re-drilling, re-excavating, and having to plug and seal the well a second time creates a significant increase in costs that could have been avoided if the original plugging and sealing was properly completed.

3) Selecting Plugging Materials

A) Filling Materials

Clean, washed sand or gravel is placed in large voids, bedrock fracture areas or adjacent to water producing zones to:

- support the abandonment barrier,
- prevent leakage of the abandonment barrier into the groundwater resource or formation, and
- restore natural groundwater flow at the well site.

Clean gravel, sand, silt or clay is placed in large diameter wells [≥ 65 cm (2.1ft)] to reduce the quantity of abandonment barrier required to seal the well and to provide increased load bearing strength.

Clean

with respect to gravel, sand, silt or clay, means that it should at least:

- be washed with clean water to remove finer textured material in the case of gravel or coarse sand, and
- not cause an impairment of the well water.

Table 15-2: Particles Sizes For Fill Materials

Material	Particle Diameter	Characteristics
Clay	≤ 0.002 mm	• Particle too small to be seen with the naked eye • Forms putty when wet • Feels smooth between fingers • Cohesive • Low permeability
Silt	0.002 – 0.05 mm	• Particle too small to be seen with the naked eye • Sometimes form putty when wet • Generally feels smooth between fingers • Less cohesive than clay • Low permeability

Material	Particle Diameter	Characteristics
Sand	0.05 – 2.0 mm (0.002 – 0.08 inch)	• Particle can generally be seen with the naked eye • Feels gritty between fingers • Commonly associated with beaches • Medium to high permeability
Gravel	2.0 – 75.0 mm (0.08 – 3.0 inches)	• If about the size of a pea, referred to as "pea gravel" • High permeability

These filling materials are mined at local pits and quarries and either sold at the pit or quarry or at building and material supply stores.

Best Management Practice – Use Table 1 in Soil, Groundwater and Sediment Standards to Meet Parameter Concentrations in Filling Materials

To ensure gravel, sand, silt or clay placed in an abandoned well is clean, the person who works at the abandonment of the well should consider having all gravel, sand, silt or clay meet the parameter concentrations of Table 1 in Soil, Groundwater and Sediment Standards for Use under Part XV.1 of the *Environmental Protection Act* April 15, 2011. The table is located on the Ontario website.

It is up to the person abandoning the well to ensure that the filling materials are clean prior to their installation into the well.

B) Abandonment Barriers

The *Wells Regulation* - Depending on the diameter of the well, the abandonment barrier must be a slurry consisting of:

- clean water and at least 20% bentonite solids by weight,
- clean water, Portland cement and not more than 5% bentonite,
- clean water and Portland cement,
- clean water, Portland cement and clean sand,
- equal weights of Portland cement and clean gravel, mixed with clean water, or
- clean water, Portland cement, clean sand and clean gravel (sometimes called a concrete slurry).

The *Wells Regulation* - The abandonment barrier can also be either:

- bentonite chips or pellets that have been screened and placed in accordance with the manufacturer's specifications, or
- other material approved in writing by the Director, if the Director is of the opinion that the performance of the other material is the equivalent of the performance of a slurry referred to above.

Reminder: For further information on the type of abandonment barrier to be used in a well see the abandonment barrier information presented in the "Plainly Stated" section and the "step 3: Plugging and Sealing To Within 2 Metres (6.6 Feet) of the Ground Surface" section in this chapter.

Cement

Neat cement is a mixture of one 43 kilogram (94 pound) bag of Portland cement (Type I or IA) to not more than 19.7 litres (4.3 Imperial gallons) of clean water. The person adding the water needs to ensure all lumps of solids are removed in the mixture. Adding more than 19.7 litres (4.3 Imperial gallons) of water per bag will create a thinner mixture. Thinner mixtures will have reduced strength and may cause shrinkage and open crack issues. Portland cement is readily available at building supply stores. Other grades of Portland cement used in the industry are American Petroleum Institute (API) cements classified as B, C, G, H, K, M and S which may be used depending on the sulphate concentrations or when there is a need for retarders/retardants or accelerators with the cement. Further information on cement can be found at the following website titled Cement and Concrete Basics.

Concrete

Concrete grout is a mixture of neat cement (see above) with a specific quantity of sand and/or gravel. Concrete is readily available or can be made on-site by mixing one 43-kilogram (94-pound) bag of Portland cement with 0.03 cubic metres (1 cubic foot) of sand or gravel and not more than 19.7 litres (4.3 Imperial gallons) of water.

Reminder: See the "Mixing Cement or Concrete Grout (Sealant)" section in Chapter 6: Annular Space & Sealing, for further information on mixing cement and concrete with water.

Bentonite

Sodium bentonite is a manufactured product that is made from volcanic deposits of sodium montmorillonite clays. The product comes in a powder form for mixing with water. The product also comes in chip, pellet and granular forms that may be added directly into the well water or that may be hydrated prior to adding to the well. When water is properly mixed with the sodium bentonite, the mixture should look like oatmeal porridge. When it hydrates (sets) it should resemble peanut butter. A proper mixture of 20% solids by weight should be a mixture of 91 L (20 Imp gal) of clean water to 23 kgs (50 lbs) of dry sodium bentonite powder. The mixture will generate a material volume of about 100 L (or 22 Imp gal).

Reminder: See the "Mixing Cement or Concrete Grout (Sealant)" section in Chapter 6: Annular Space & Sealing, for further information on mixing cement and concrete with water.

Sodium Bentonite with Cement

In some cases 3 % to 5 % bentonite by weight is used as an additive to cement or concrete to improve the workability (make it more fluid), weight and density of the cement slurry. Bentonite is chemically incompatible with cement and will not swell significantly in a cement slurry. The bentonite additive also reduces the set strength of the seal, lengthens set time, increases shrinkage and open cracking. For these reasons, bentonite must not exceed 5% of the mixture by weight.

Table 15-3 in this chapter provides some general information on advantages and disadvantages of cement and bentonite based abandonment barriers.

Table 15-3: Some General Abandonment Barrier Advantages And Disadvantages

Abandonment Barrier	Advantages	Disadvantages
Bentonite Based Abandonment Barriers	• Suitable low permeability with high solids by weight grouts • Generally non–shrinking and self–healing • No heat generated during hydration • Low density • Sodium bentonite products expand to about 12 to 15 times their original dry volume allowing for less material to be required • Short curing time. To achieve full gel strength bentonite takes 8 to 48 hours. • Properties such as density can be altered with additives	• Mineralized groundwater (e.g. ≥ 5,000 mg/L of total dissolved solids or ≥ 8,000 mg/L chlorides) will inhibit the hydration process and its effectiveness as a sealant. This includes source water used in mixing bentonite for a grout. • Groundwater characteristics, such as excess hardness (i.e., ≥ 500ppm total hardness) or chlorides (i.e., ≥ 1500ppm) may make bentonite an inappropriate choice as a sealant for the environment as it may not properly set [2] • Flowing well environments will likely diminish its effectiveness because it does not have the necessary weight and gel strength to overcome the water pressure • When filling the annular space, bentonite grouts can leak out into open fractures in bedrock environments due to its weak strength • May have an impact on the groundwater chemistry and the well components because it can trade off cations such as sodium, aluminium, iron and manganese • Additives that may be added to the bentonite slurry (organic and inorganic polymers) may affect groundwater chemistry near the well • High solids bentonite are not suitable for use at the surface for arid climates due to potential for dehydration causing cracking and thus, will not perform as a long term effective abandonment barrier material • For some grout mixtures with significantly high bentonite solids content (≥ 35%), rapid swelling rate and high viscosity can result in difficult pumping through grout pumps and tremie pipes

Abandonment Barrier	Advantages	Disadvantages
Cement Based Abandonment Barriers	• Suitable low permeability • Easily mixed and pumped • Hard–positive seal provides structural integrity (good gel strength) and will not erode or wash-out with water movement • Supports and adheres to casing • Any remaining casing is rendered permanent and non–movable • Adheres well to bedrock • Properties can be altered with additives to reduce hydration time (calcium chloride), to make it stronger (aluminum powder), or have a higher resistance to sulphate rich environments (fly ash). • Expanding Portland cements, types K, M and S, have characteristics and shrinkage-compensating additives that work well as abandonment barriers • Air-entrained cements work well in cold weather climates because cement with air-entraining agents has water tightness and freeze thaw resistance. • Provides weight and strength to overcome pressures associated with flowing wells	• Possible shrinkage if extra water is used, if improper additives are used or if the person is not using shrinkage compensated cements • Settling problems occur if not properly mixed or placed • Long curing time (minimum 12 hours) increases time to complete well and remove casing in well • Produces high heat levels during hydration process that can distort some plastic casings. The high heat of hydration in combination with weight of grout also increases the potential for plastic casing to distort or collapse. • High density results in loss of grout to some permeable overburden and bedrock formations • If prompt equipment clean–up does not occur, cement equipment damage may result • In order to properly set, mixing water needs to be cool, clean and fresh. Water also needs to be free of oil soluble chemicals, organic material, alkalies, sulphates and other contaminants • In order to properly set, mixing water needs to have a total dissolved solids concentration of less than 500 mg/L • Using water that has a high pH may increase setting time. • Equipment such as a tremie pipe needs to be kept cool to prevent flash set problems to pumps and tremie pipes • If too much water is used in the mixture, the extra water cannot chemically bind with cement (called bleed water), becomes highly alkaline and then can percolate through the cement. Voids in the cement created by this bleed water can also be subject to chemical attack and thus, will not perform as a long term effective abandonment barrier material • Prolonged mixing can interrupt heat of hydration process and reduces strength and cement quality • Neat cement mixtures increase the pH in the subsurface formations.

C) When Contaminants Or Naturally Occuring Mineralized Water Are Present

The *Wells Regulation* - In choosing an abandonment barrier, the material must:

- be compatible with the quality of the water found in the well. In some cases, sulphate rich waters will react and destabilize Type I Portland cement. In some salt rich waters, sodium bentonite will not set properly and destabilize.
- not contain any materials that may impair the integrity of the abandonment barrier, including soil or drill cuttings.
- be stable in the presence of any contaminants. If contaminants such as gasoline, fuel oil or nutrients are present in the groundwater or formation, the person abandoning the well will need to ensure that a proper plugging material is chosen. Unstable materials may not properly set and may affect the integrity of the structure.

Reminder: When in doubt, a small sample batch of the intended abandonment barrier should be mixed and placed in container with a sample of the well water. Observe any reactions.

D) Alternate Abandonment Barrier Products (Director's Written Approval)

The *Wells Regulation* allows for the use of seven types of abandonment barrier materials which are described in section 3) B) of this chapter. In some cases, approved abandonment barrier materials may not be suitable for the environment or available for the plugging and sealing operation, therefore, other materials may be used if written consent is provided by the Director.

Prior to well abandonment, the person abandoning the well, often the well owner, may apply and seek the written consent of the Director to use a type of abandonment barrier material other than the seven abandonment barriers in section 3) B) of this chapter as long as the performance of the material is at least equivalent to the performance of the listed abandonment barriers.

How Can the Person Abandoning a Well Request and Obtain a Written Consent From the Director?

The person abandoning a well, often the well owner, may contact the Wells Help Desk:

- in writing to Wells Help Desk, Ministry of the Environment and Climate Change, 125 Resources Road, Toronto, ON M9P 3V6,
- by fax at: 416-235-5960, or
- by e-mail at Wellshelpdesk@ontario.ca.

For further information, the well owner can contact the Wells Help Desk by telephone at (for Ontario residents only).

The person abandoning a well, often the well owner, should provide a written request with the following information:

- the name of the individual(s)/entity that owns the well,
- the location of the well,
- an indication as to whether or not the well in question is new or an existing well,
- the purpose and use of the well,
- the reason for the alternate abandonment barrier request (e.g., contaminant(s) of concern encountered or trying to stop a flowing well), and
- if applicable, written certification for the use of an alternate barrier material by the manufacturer or a Professional Engineer.

The person abandoning a well may be required to retain a Professional Engineer or Professional Geoscientist who would have to prepare a scientific report showing the appropriate scientific rationale to support the application. The person abandoning a well would have to submit the report along with the request for written consent to the Ministry for its consideration.

Depending on the case, and as part of the Director's consideration, the Director may ask other regulators and interested parties to comment on the application.

How Does the Director's Decision Process Work?

The request for written consent must be submitted to the Director along with any and all supporting documents such as a hydrogeological, well plugging design and/or abandonment barrier design report(s). The person abandoning the well and others should be aware that obtaining a written consent will not be an automatic process. The Ministry has to provide for the conservation, protection and management of Ontario's waters and for their efficient and sustainable use, to promote Ontario's long-term environmental, social and economic well-being.

The Director will review the request, supporting information and other information generated from internal and external parties with an interest in the application. Based on the review, the Ministry will contact the person abandoning the well, in writing, indicating the Director's decision

4) Estimating Plugging Material Volumes Required

Table 15-4 may be useful to estimate how much cement, concrete or sodium bentonite plugging material is needed to plug a well. Further calculations are provided in "Calculating Amount of Materials Required" section of Chapter 6: Annular Space and Sealing, Calculating Amount of Material Required section.

When plugging wells into bedrock or gravel deposits, large open fractures or open void spaces around the well can cause material to leak out of the well and into the formation. This and other hole irregularities (e.g., Figure 15-6) can increase the volume of plugging material required. Extra material should be available in the event there is an underestimation.

Table 15-4: Estimated Volume Of Material For Different Well Diameters

Well Diameter Centimetres	**Well Diameter Inches**	**Metres (Feet) of Well Plugged Using One Bag of Neat Cement** [***] **43 kg (94 lbs) bag**	**Metres (Feet) of Well Plugged Using One Bag of Concrete** [**] **43 kg (94 lbs) bag**	**Metres (Feet) of Well Plugged Using One Bag of Sodium Bentonite** [*] **23 kg (50 lbs) bag**
3	1 ¼	42 m (138 ft)	76 m (250 ft)	126 m (413 ft)
6	2 ¼	13 m (43 ft)	24 m (77 ft)	39 m (127 ft)
8	3 ¼	6 m (20 ft)	11 m (37 ft)	19 m (61 ft)
11	4 ¼	4 m (12 ft)	7 m (22 ft)	11 m (36 ft)
13	5 ¼	2 m (8 ft)	4 m (14 ft)	7 m (23 ft)
16	6 ¼	1.7 m (6 ft)	3 m (10 ft)	5 m (17 ft)
21	8 ¼	1 m (3 ft)	1.7 m (6 ft)	2.9 m (9 ft)
26	10 ¼	0.6 m (2 ft)	1.1 m (4 ft)	1.9 m (6 ft)
31	12 ¼	0.4 m (1.4 ft)	0.8 m (2.6 ft)	1.3 m (4.3 ft)

Well Diameter Centimetres	Well Diameter Inches	Metres (Feet) of Well Plugged Using One Bag of Neat Cement [***] 43 kg (94 lbs) bag	Metres (Feet) of Well Plugged Using One Bag of Concrete [**] 43 kg (94 lbs) bag	Metres (Feet) of Well Plugged Using One Bag of Sodium Bentonite [*] 23 kg (50 lbs) bag
61	24	0.11 m (0.4 ft)	0.21 m (0.7 ft)	0.34 m (1.1 ft)
91	36	0.05 m (0.2 ft)	0.09 m (0.3 ft)	0.15 m (0.5 ft)

Reminder: The formula in this table is based on the industry standard well casing diameter in inches for drilled wells and some dug wells. The calculated numbers have then been rounded

5) Preparing Equipment, Selecting Methods And Obtaining Approvals Needed To Plug The Well

Prior to plugging the well, the following should be determined:

- The type of heavy equipment needed to remove structures, casings, screens and well equipment. This could include a drilling rig, excavator (backhoe or high hoe), water trucks, cement trucks, gravel trucks, cement pumping trucks, stake trucks containing extra casing, welding materials, and other tools.
- The location of nearby pits and quarries that supply filling materials such as gravel. The location of retailers of cement or bentonite will also be important in choosing the materials and methods to plug the well.
- A source of high quality clean water for preparing a slurry.
- The type of specialized equipment such as fishing tools or casing cutters to remove collapsed casing, obstructions or equipment stuck in the well.
- The type and method of installing the plugging materials in the well such as tremie pipes, attachments to casings and grout pumps.
- The location for disposing of any contaminated materials that are removed at the well site.
- Appropriate health and safety precautions. See the Safety Manual for Well Technicians [3] and the Ministry of Labour's website for additional information.

- Any approvals, permits or other instruments that may be necessary before the operation commences. For example:

    - If groundwater is anticipated to discharge from a well before abandonment, or is discharging from a well during abandonment, at a volume of more than 50,000 litres (11,000 imperial gallons) on any one day, a Permit To Take Water under the *Ontario Water Resources Act* must be required. More information on Permit To Take Water approvals can be found on the Ontario website.
    - The person abandoning the well must ensure that the groundwater, debris and other materials discharging from the well do not cause adverse environmental impacts such as erosion, impairment of surface water courses and/or off-site flooding. This may require the use of settling pits on the property. A sewage works environmental compliance approval under the *Ontario Water Resources Act* may be required if the person abandoning the well discharges the water, drill cuttings or other material and the discharge capacity exceeds 10,000 litres per day. A guide to explain the sewage works process can be found on the Ontario website.

6) Determining If Overdrilling Is A Best Management Practice

In some cases plugging a well without removing the casing and well screen may not effectively seal the well to prevent the vertical movement of surface water, contaminants and other foreign materials. Some examples include:

- An annular space (open space beside the casing) may exist below the ground surface in some wells. The open space can act as a pathway for contaminants to move between formations.
- The casings of a multiple diameter cased well (well with dual walls) may be adjacent to one another and the space between them may not be properly sealed. The space between the casings can act as a pathway for contaminants.

In these situations, a person abandoning a well could consider overdrilling the well (see Best Management Practice titled "Overdrilling the Well" in this section).

Best Management Practice – Overdrilling the Well

Overdrilling should be used in situations where the casing or well screen cannot reasonably be removed, and where leaving them in the well may inhibit the formation of an effective seal that prevents the vertical movement of surface water, contaminants and other foreign materials.

The overdrilling method involves using a rotary drilling machine with a specialized drill bit that is larger than the filled annular space of the well. The specialized drill bit can cut casing and well screen that is made out of steel or plastic. In certain overburden deposits, hollow-stem auger flights can be used to overdrill around the casing.

The casing, well screen and other material in the well and the well's annular space are removed by the drilling operation. The open hole is held open by temporary casing. In some cases, bedrock, till and clay formations, may have sufficient strength to prevent well collapse and would not require the use of a temporary casing. The open hole can then be filled with the appropriate abandonment barrier material and other filling material using the nine step sequential method (see the "Nine Sequential Step Procedure to Plug and Seal a Well" section in this chapter).

The method offers assurance that the entire hole is filled with abandonment barrier or other filling materials to reduce the risk of the well acting as a pathway for contaminants.

Reminder: If the well has a well tag, the well tag must be removed prior to overdrilling the well (see the "Nine Sequential Step Procedure to Plug and Seal a Well" section in this chapter).

Nine Sequential Step Procedure To Plug And Seal A Well

The person abandoning the well, often the well owner, must ensure the following nine steps are taken in sequence unless otherwise specified.

Best Management Practice – Work Efficiently and Cover Abandoned Well

To protect against safety concerns and the well acting as a pathway for contaminants, the person abandoning the well should ensure the person working on the well:

- manages equipment, time and resources to complete the plugging and sealing steps in one day or less, and
- covers the well in a manner that prevents the entry of surface water and other foreign materials if the person working on the abandoned well leaves the site before completing the plugging and sealing steps.

1) Safeguarding And Returning The Well Tag

The *Wells Regulation* - If the well has a well tag, it must be removed and returned to the Director within 30 days after its removal.

Since August 2003, persons constructing wells have been required to affix Ministry issued well tags onto new and altered wells.

If the well has a well tag attached to the well casing or near the well, the well tag must be removed at the beginning of the plugging operation and safeguarded throughout the process.

The well tag must be returned within 30 days after completion of abandonment and removing the tag. The well tag must be returned to Wells Help Desk, Ministry of the Environment and Climate Change, 125 Resources Road, Toronto, Ontario, M9P 3V6 ().

Figure 15-10: Well Tag On Drilled Well

2) Removing Equipment, Structures, Debris And Any Collapsed Well Casing And/Or Well Screen

2(A) Structures And Slabs

In some cases, wells are housed in well pits or pump houses to protect the well head from the winter environment or to house pumping and electrical equipment near the well. There are also cases where wells are housed in buildings. Removal of slabs and structures can be done at any time before step 8 ["Plugging and Sealing the Upper 2 Metres (6.6 Feet)" section in this chapter] is undertaken.

Best Management Practice – Remove Concrete Slabs or Pump House As Soon As Possible

If the well is located within a pump house, has a protective well cover or there are slabs of concrete surrounding the well casing at or near the ground surface, the pump house, protective well cover or the concrete slabs, should be removed to the extent practical, at the start of the abandonment of the well. Any barriers should also be removed to allow for abandonment equipment to access the well. The well should be properly covered and maintained up to the time the well is deemed abandoned and properly plugged and sealed.

Figure 15-11: Drilled Well Inside A Pump House

Figure 15-11 shows a drilled well, waterline, and pump located within a pump house. The pump house floor is a concrete slab.

Reminder: In cases where wells are housed in residential dwellings or other types of buildings and there is continued use of the building, see Step 7 "Removing Below Ground Concrete Structures and Slabs" section in this chapter for additional details.

2(B) Removing Equipment

The person abandoning the well must ensure the person working at the abandonment of the well removes all pumping equipment, waterlines (drop pipes), electrical equipment, connections, pipes, and other equipment from the well.

Figure 15-12: Electrical Cables

Figure 15-13: Electrical Cables - Close Up

Electrical cables going into a drilled well to a submersible pump, as shown in Figure 15-12 and Figure 15-13, are a safety hazard if they are damaged or not properly disconnected and removed.

Figure 15-14: Equipment Required To Be Removed

Figure 15-14 shows pumping equipment (drop pipe) extending out of the well without a watertight seal on the top of the casing. Removal of pumping equipment, including the drop pipe, from the drilled well is necessary prior to the installation of the abandonment barrier material. The removal of the equipment will help ensure that the entire well is properly plugged.

2(C) Removing Collapsed Well Casing And Well Screen

Over time, steel well casing can corrode and plastic well casing can degrade or crack. Corrosion, degradation or cracks create openings and allow the migration of contaminants.

If possible, broken well casing or well screen should also be removed from the well. There are a variety of drilling tools that can be used to remove broken casing and well screen. For example a backhoe or highhoe can remove casing in overburden environments up to about 9 metres (30 feet) below the land surface.

Figure 15-15: Removal Of Well Casing

Figure 15-15 shows the removal of well casing using a drilling rig with a chain attached to the rig's winch.

Figure 15-16: Removal Of Well Casing

The drilling rig raises the chain and casing out of the ground leaving the well open. The rig has removed the casing from the well.

Figure 15-17: Removal Of Well Casing

Another method of casing removal is to attach the upper portion of casing to a casing rotator. The casing is being raised up the drilling mast.

Figure 15-18: Tapered Tap

A tapered tap, such as the one shown in Figure 15-18, is used to spear the broken casing. The device is lowered from the drill rig. Once attached into the casing, the drill rig can raise the casing out of the well. Other similar attachments that can be used are a sandlock or trip spear.

Figure 15-19: Casing Cutter

This white casing cutter shown in Figure 15-19 is attached to drill rods on the drill rig. The cutter and drill rods are lowered into a cased well to the desired elevation by the drill rig and operator. The cutter and drill rods are rotated by the drill rig. During the rotation, the cutter (the grey steel in centre of the white cutter) will cut the well casing.

Figure 15-20: Casing Cutter

Figure 15-20 shows a blue casing cutter that has been removed from the top head drive of the drill rig. The casing cutter was originally attached to the bottom of drill rods and placed in the well using the drill rig. The casing cutter was used to cut the casing at the predetermined depth below the ground surface. The top of the casing is shown below the rotator table on the right side of the photograph. The rotator table will attach to the casing and pull the cut piece of casing out of the well.

Cutting a length of casing and leaving some casing in the ground is allowed if it is not reasonably possible to remove the entire casing while sealing the well with abandonment barrier.

Figure 15-21: Corroded Casing From Inside

Figure 15-22: Corroded Casing From Outside

Figure 15-21 and Figure 15-22 show the interior and exterior of a drilled well with casing corroded to a point that a significant hole has formed through the well casing. The hole is seen on the right side of Figure 15-21 and can also be seen in Figure 15-22. The open hole acts as a pathway for surface water and other foreign materials to enter and contaminate the well water.

Reminder: During the removal process of large diameter concrete well casing, reasonable efforts must be made to remove any broken concrete tiles from the well before proceeding with further plugging and sealing steps.

Best Management Practice – Abandoning a Well with Collapsed Well Casing

When abandoning a well that has a collapsed well casing, the person abandoning the well should retain a Professional Engineer or Professional Geoscientist. The professional should assess the well. The casing and equipment should be removed by an experienced licensed well technician who holds a well contractor licence or who works for a licensed well contractor. A video camera assessment of the well can assist in the identification and location (depth) of problems in the casing, obstructions and equipment. Solutions may include using fishing tools, re-drilling, overdrilling or excavating the well.

Reminder: The person working on the abandonment can remove intact well casing before step 3 if the person working on the abandonment uses an overdrilling method to rip out the entire well including the casing. See the “Plainly Stated” section in this chapter and step 6 “Determining if Overdrilling is a Best Management Practice,” in this chapter for further information on overdrilling.

2(D) Removing Obstructions

If obstructions are not removed from abandoned wells before plugging, the lower portion of the well below the obstruction will not be effectively plugged, resulting in an open conduit for contaminant migration.

Obstructions may include any of the following:

- Pumping equipment
- Devices to measure water levels, water quantity or well water quality such as flow meters, or pressure transducers
- Materials that have inadvertently or naturally entered the well
- Inflatable packers used to stop well water from discharging out of a flowing well
- Pitless adapters, grounding devices, well seals and caps

Figure 15-23: Drilled Well Partially Filled With Concrete

Figure 15-23 shows the view inside a drilled well that has only been partially filled with concrete. There is also an unsealed portion of the well below the concrete plug (not visible). The concrete needs to be carefully drilled out by an experienced well driller prior to properly plugging and sealing the well.

Figure 15-24: Pitless Adapter On Outside Of Casing

Figure 15-24 shows the outside of the well casing from ground level with a pitless adapter and horizontal waterline extending from the well. The pitless adapter needs to be removed from this well casing prior to plugging and sealing. Also, the photograph shows a large opening on the outside of the well that will need to be filled.

Figure 15-25: Pitless Adapter On Inside Of Casing

The pitless adapter shown in Figure 15-25, is located just above the well water level and extends through the left side of the drilled well casing. The pitless adapter needs to be removed along with the drop pipe, and the submersible pump's three coloured electrical wires, the cable and rope.

Figure 15-26: Waterlines, Air Vent And Seal To Be Removed

Figure 15-26 shows two waterlines, an air vent and a sanitary well seal which need to be removed from the top of well casing located on the floor of this well pit. The person also needs to ensure the concrete tiles and the fungus in the well pit are removed.

2(E) Removing Debris

All debris, including biofilm must be removed from the well to ensure that it will not interfere with the setting of the plugging material and not impair the groundwater.

Figure 15-27: Debris To Be Removed

The debris shown in the dug well in Figure 15-27 consists of wood, pipe, sticks and leaves which may interfere with the plugging material's (abandonment barrier's) performance.

Examples Of Methods For Removing Debris And Biofilms

Submersible Pump Method

One method of removing debris involves the installation of a clean submersible pump and drop pipe in the well. The pump, wires and drop pipe should be soaked in a solution of fresh unscented bleach and clean water prior to installation.

Best Management Practice – Removal of Well Water Column as Part of Debris

As part of the removal of debris and biofilm from the well, it is recommended that, where feasible, at least 20 volumes [4] of the water column in the well be removed. The volume of the water column in the well should be calculated by measuring the top of

the water level (static water level) and well depth. The difference between the two measurements provides the height of the water column in the well. If the well is not very deep an example of a measuring device that may be used is a calibrated tape measure. For accurate measurements in deep wells, a calibrated electrical water level meter should be used.

The well water removal process will also remove some of the organic biofilm such as iron bacteria that may have built up on the sides of the well. Biofilm can spread through an aquifer to other wells and inhibit chlorination processes. See the "Other Chemical Treatment" section in Best Management Practice – Using Shock Chlorination Where Appropriate" in this chapter.

As an example, if a 16 cm (6 ¼ inches) diameter drilled well contained a column of 10 m (33ft) of water, the well would hold about 200 L (or 44 Imp gal) of water. Thus, at least 4,000 L (or 880 Imp gal) should be pumped from the well.

A pail and timer (e.g., an accurate watch or stop watch) can be used to measure the pumping rate. The pump should be kept at a constant rate using appropriate equipment such as a dole valve, globe valve or ball valve.

For example if a person needed to pump 4,000 L (880 Imp gal) of water and has a 20 L (4.4 Imp gal) pail, the person can observe the seconds it takes for the pumped well water to fill up the pail. If it takes 1 minute for the 20 L pail (4.4 Imp gal) to completely fill, then at least 200 minutes of pumping would be needed to remove 4,000 L (880 Imp gal) of water from the well.

Reminder: For information on proper handling of discharge water and relevant approvals see "Conducting the Yield Test" section and "Handling Water Discharge" section in Chapter 10: Yield Test. If approvals are necessary, it is important that they be obtained before starting to remove (pump) the well water.

Table 15-5 provides different well diameters and the estimated volume of water per metre (or foot) in the well. Multiplying the height of the water column by the estimated volume per metre (or foot) will provide the estimated volume of water in the well column.

Table 15-5: Estimated Volume Of Water For Differently Well Diameters

Well Casing Inner Diameter (Centimeters)	Well Casing Inner Diameter (Inches)	Volumes of Water (Litres per metre)	Volumes of Water (Imperial Gallons per Foot)
3	1 ¼	0.8	0.05
6	2 ¼	2.6	0.17
8	3 ¼	5.4	0.36
11	4 ¼	9.2	0.61
13	5 ¼	13.9	0.94
16	6 ¼	19.9	1.33
21	8 ¼	34.6	2.31
26	10 ¼	53.1	3.57
31	12 ¼	76.0	5.09
61	24	292.2	19.55
91	36	656.1	43.99

Reminder: The formula in this table is based on the industry standard well casing diameter in inches for drilled wells and some dug wells. The calculated numbers have then been rounded

Figure 15-28: Pumping With A Submersible Pump

Figure 15-28 shows a submersible pump and waterline installed into the well. Using a generator on the back of the pickup truck as a power source for the pump, well water and debris are being pumped out of the well and discharged on the ground surface at a safe location.

Compressed Air Method

In some cases, drilling machines blowing air are used to remove water with the debris and a portion of biofilm from the well.

Reminder: For information on proper handling of discharge water and relevant approvals see "Conducting the Yield Test" section and "Handling Water Discharge" section in Chapter 10: Yield Test. If approvals are necessary, it is important that they be obtained before starting to remove (pump) the well water.

Figure 15-29: Compressed Air Removal Of Debris

The person operating the rotary rig in Figure 15-29 is using a compressor to blow air under high pressure and a high rate through drill rods into the well. The air forces well water and debris up the well to the ground surface. In this case, the well water is not contaminated.

Best Management Practice – Using "Shock" Chlorination Where Appropriate

To ensure potential disease causing organisms in the well water or groundwater near the well do not move with groundwater flow to other area wells, well water should be "shock" chlorinated, where appropriate, prior to the plugging and sealing of a well (see Chapter 8: Well Disinfection for further information). If biofilm from organisms such as iron bacteria or sulphate reducing bacteria is present, mechanical and chemical cleaning are recommended prior to chlorinating the well.

However, "shock" chlorination is not appropriate for certain wells sites where free chlorine can create chlorinated contaminants (see If Chlorination of Well Water Presents a Hazard below).

Sodium hypochlorite (unscented bleach) is commonly used in the chlorination process. Bleaches are available at local grocery and hardware stores. Other products may be used to chlorinate water such as calcium hypochlorite and lithium hypochlorite. Commercial bleach at 12% available chlorine is also used by many well contractors. Correct calculations must be made when using this product to ensure proper concentrations in the well. Proper safety procedures need to be employed when handling sodium hypochlorite or the other oxidization agents since they are harmful to humans (see Chapter 8: Well Disinfection for further information).

Chlorinating the Well

"Shock" chlorination should target a free chlorine residual in the range of 50 to 200 milligrams per litre to remove pathogens from well water (see Chapter 8: Well Disinfection). To obtain the target concentration range in the well see the formulae, and tables in Chapter 8: Well Disinfection).

The formulae do not consider metals and organics that will consume the solution prior to creating the oxidizers in the water. As such, free chlorine residual test equipment should be used to verify a free chlorine residual in the well water. Common methods to measure the free chlorine residual such as a colour-wheel test kit and digital colorimeters are shown in Chapter 8: Well Disinfection.

Discharging Chlorinated Well Water

It is important, that at the end of treatment period the chlorinated well water be pumped from the well to a suitable storage tank, neutralized, and then discharged to a location that will not cause an adverse effect on the natural environment. It is also important that the chlorinated water from the well be pumped to ensure it does not move through the aquifer and impair nearby wells or surface water (see Chapter 8: Well Disinfection for further information).

If Chlorination of Well Water Presents a Hazard

Where the chlorinated water may cause an adverse health reaction or hazard when mixed with other chemicals present in the well water and groundwater, the well contractor and well owner should not chlorinate the well.

Some situations where well chlorination treatment should not occur may include groundwater contaminated with arsenic or with a high naturally occurring arsenic concentration. The addition of sodium hypochlorite may elevate arsenic in the groundwater near the well.

In other cases, a nearby well may be hydraulically connected to the well being chlorinated. The chlorinated water may move from the abandoned well to a nearby well and impair the quality of the well water. As such, chlorinating the well before plugging should either not occur or proceed with monitoring of the nearby well. A contingency plan that is ready to be activated to prevent any adverse effects should be in place.

Other Chemical Treatment

In some cases, acid blends using specific biodispersants or other chemical treatments are used to dislodge biofilm and other encrustations from the sides of the well. The biofilm may then be mechanically cleaned andremoved from the well by pumping or compressed air. Only qualified and licensed professionals should conduct these specialized methods and treatments (see Chapter 11: Maintenance & Repair for additional information).

3) Plugging And Sealing Within Two Metres Of Ground Surface

The *Wells Regulation* - The abandonment barrier must be placed in the well, including any annular space, in a manner described in this section until a depth of about 2 m (6.6ft) below the ground surface is reached.

This does not prevent the placement of clean, washed sand or gravel adjacent to water producing zones or bedrock fractures to minimize the loss of abandonment barrier (sealant) material.

The abandonment barrier must be placed in a manner that prevents any movement of water, natural gas, contaminants or other material between subsurface formations (which include aquifers) or between a subsurface formation and the top of the abandonment barrier material.

Reminder: See the “Determining if Overdrilling is a Best Management Practice” section in this chapter when determining if the annular seal, filter pack or other material beside the casing should also be sealed.

The *Wells Regulation* identifies different methods for placing plugging materials into wells depending on the diameter of the well.

3(A) Well Diameter Greater Than 6.5 cm (2.6 inches)

These medium and large diameter sized wells are typically drilled wells. Larger diameter dug and bored wells can follow this option or the alternative option listed in Step 3 (C) in this chapter. See Table 15-1 for further information of small, medium and large diameter wells.

The abandonment barrier used to plug these wells can consist of neat cement, concrete and sodium bentonite slurries, sodium bentonite chips or pellets, mixtures of not more than 5% sodium bentonite with neat cement or a plugging material approved by the Director (See “Selection of Plugging Materials” section in this chapter).

Best Management Practice – Taking Precautions when Using Dry Bentonite Products

If sodium bentonite pellets or chips are used, the material needs to be screened and placed in accordance with the manufacturer’s specifications. Precautions when plugging a well with dry bentonite products include:

- ensuring sealing material does not bridge when placing material,
- pouring the products at a rate no faster than 3 minutes per 22 kilogram (50 lb) bag,
- using pellets or chips that are coated with a material that increases the length of time before bentonite starts to swell once it contacts water,
- halting the pouring process occasionally and lowering a weighted measuring tape into the well until it reaches the top of the products to confirm that bridging has not occurred,
- using a tamping device to break any bridges that form, and
- making sure bentonite is continually hydrated, where necessary, by periodically adding clean water to the bentonite that has been placed in the well.

If sand or gravel is used to fill the water producing zones or open fractures in bedrock, similar precautions to those used for sodium bentonite pellets or chips should be followed.

Figure 15-30: Bentonite Chips

Figure 15-30 shows medium sized manufactured bentonite chips.

Figure 15-31: Pouring Bentonite Chips

Figure 15-31 shows a licensed well technician pouring bentonite chips in an abandoned well. In this case the well casing and well screen were originally removed using an overdrilling technique. This hole remained open after casing removal and overdrilling because the overburden deposit has sufficient strength and stability to prevent formation collapse. In other cases, a temporary casing or auger flight may need to be installed to hold the hole open. Manufacturers have different specifications for screening and placement of bentonite chips or pellets; this figure shows one example.

Figure 15-32: Hydrating Bentonite Chips

Figure 15-32 shows a licensed well technician periodically adding clean water to the hole shown in Figure 15-31. The addition of clean water allows the bentonite chips that have been placed into the hole to hydrate and form a seal in the well.

If a slurry abandonment barrier is used, the best abandonment barrier material that will properly plug and seal the well should be chosen (See Selection of Plugging Materials in this chapter).

The *Wells Regulation* - Any wet abandonment barriers (i.e., slurries) must be placed in the well (including the annular space) from the bottom of the well using a tremie pipe with the bottom of the pipe immersed in the rising accumulation of the abandonment barrier.

Care needs to be taken to ensure that the tremie pipe does not become stuck in the abandonment barrier within the well. This will include raising the tremie pipe during the operation.

The tremie pipe typically extends from a grout mixing machine and pump at land surface to the bottom of the well as shown in Figure 15-36. As an alternative, a pipe is sometimes attached from the grout mixing machine and pump to the top of the well casing. The casing is then used as the tremie pipe as shown in Figure 15-37.

If well water, and any material displaced during this operation is contaminated (e.g., contains gasoline), the water must be collected and disposed of in an approved manner. No person shall discharge the contaminated water and waste material that causes or may cause an adverse effect to the natural environment.

The person abandoning the well will need to properly store or transport the contaminated water and waste material.

If a person wishes to haul contaminated water or waste material to a regulated waste disposal site, the person must have an approved waste management system (i.e., holds a valid certificate of approval) to carry the contaminated water or waste material, must meet the requirements of the *General – Waste Management Regulation* (*Regulation 347* as amended made under the *Environmental Protection Act*) and must dispose of the contaminated water or waste material at a licensed facility that is listed on the certificate of approval. A guide to explain approved waste management systems can be found on the Ontario website.

If the displaced water is not contaminated, it should be directed away from the well site to minimize the likelihood of the water flowing into the well opening. For information on proper handling of discharge water and relevant approvals see the “Handling Discharge Water” section in Chapter 13: Water Level Measurements, Aquifer Testing and Discharge Water Handling.

Figure 15-33 to Figure 15-39 show some grout mixing equipment and methods of plugging and sealing wells.

Figure 15-33: Grout Mixing Machine

Figure 15-33 shows a grout mixing machine. Material is placed and mixed in an upper tray and then transferred to a lowered into a lower tray, where it is pumped through a tremie pipe (not shown) to the well behind the drilling rig. It is not recommended to use dual tank grout mixing units with bentonite based grout because separation of the product and water can occur when grout is not agitated in the pumping tank. This results in a flash setting of grout in the tremie line or non-uniform grout consistency.

Figure 15-34: Another Grout Mixing Machine

Figure 15-34 shows another grout mixing machine. In this case the person working at the abandonment of the well is placing and mixing sodium bentonite powder and water in the grout mixing machine. The mixture will be pumped from the machine through a tremie pipe placed into the well.

Figure 15-35: Abandonment Barrier Materials

Figure 15-35 shows the back of a manufactured bentonite product package. As in this photograph, most manufacturers provide minimum volumes of material to water ratios on the back of their packages. Using proper ratios of material and water helps to achieve the best abandonment barrier for the environment.

Figure 15-36: Tremie Pipe Installed Into Drilled Well

In the foreground of Figure 15-36 is a drilled well steel casing. A black tremie pipe has been installed through the top of the well casing to the well's bottom. A hole has been excavated 2 metres (6.6 feet) below the ground surface around the well casing. In the background, sodium bentonite and clean water have been mixed in a grout mixing machine in the back of a pickup truck to achieve a mixture of 20% solids by weight.

Figure 15-37: Using A Casing As Tremie Pipe

Figure 15-37 shows the attachment of a large hose on to the well casing. Both the large hose and casing will be used as the tremie pipe. In this example, cement will be pumped under pressure from a concrete pump truck through the hose and into the top of the well casing. The cement will move down the casing and into the formation below the casing. Due to the pressure exerted in the pumping operation, the cement at the bottom of the casing will push up into any open annular space located near the bottom of the well casing.

Figure 15-38: Plugging Material Displacing Uncontaminated Water

In Figure 15-38 and Figure 15-39 (below), a proper slurry mixture of sodium bentonite powder and water are being pumped into a drilled well before the mixture fully cures. In the initial phase, shown in this figure, the plugging material is rising from the bottom of the well and displaces the well water. The plugging material is placed using the tremie pipe from the bottom of the well to the top of the well casing to ensure the plugging material completely fills the well.

Figure 15-39: Plugging Material Coming Out Of Casing

In Figure 15-39, the fluid coming out of the top of the well is the sodium bentonite plugging material (abandonment barrier). Pumping will stop and the person working at the abandonment of the well will wait in case the abandonment barrier settles out into other parts of the formation around the well. If settling occurs, the person working at the abandonment of the well will pump more plugging material into the well.

The intent of plugging the entire well, including the annular space, with a tremie pipe is to ensure that bridging and material segregation will not occur during grouting.

Bridging usually occurs when the plugging material is added from the ground surface into a small diameter deep drilled well at a high rate and begins to clog the hole or well casing at an elevation above the bottom of the well. This happens more frequently with dry plugging materials. As a result the material fails to properly fall to the bottom of the well creating open gaps in the well. Open gaps, due to bridging, can potentially allow contaminants to travel vertically in the open portion of well when the casing has been pulled, destabilize the structure of well, and impede the effectiveness of the plugging materials.

Material segregation may occur when the different components of a grout (e.g., concrete) vary in weight and the grout (i.e., abandonment barrier) is poured slowly from the top of the well. This segregation reduces the effectiveness of the plugging material. As with bridging, the use of a tremie pipe can eliminate the potential of any material segregation.

3(B) Wells With A Diameter Less Than Or Equal To 6.5 cm (2.6 inches) - Driven Wells

These wells are typically narrow wells such as driven point wells or possibly deep diamond drilled wells. Diamond drilled wells are typically used in mining exploration but are used as domestic wells in certain communities in Ontario. Driven point wells, typically used for domestic water takings from shallow groundwater resources, are another example of narrow diameter wells.

Reminder: When determining the diameter of a single casing well, the initial hole diameter at the time of construction must be taken into account in addition to the outer diameter of the casing.

The *Wells Regulation* - If the well casing and well screen have been removed, the abandonment barrier must be either:

- a slurry consisting of clean water, Portland cement and not more than 5% bentonite solids by weight; or

- a slurry consisting of clean water and at least 20% bentonite solids by weight.

The above also applies, with necessary modifications, to an uncased well that is less than or equal to 6.5 cm (2.6 inches) in diameter.

The *Wells Regulation* - If the well casing and well screen have not been removed, the abandonment barrier must be either:

- a slurry consisting of clean water, Portland cement and not more than 5% bentonite solids by weight, or
- bentonite chips or pellets that have been screened and placed in accordance with the manufacturer's specifications.

The *Wells Regulation* - The abandonment barrier and filling materials must be installed from the bottom of the well upward to a depth of approximately 2 m (6.6ft) below the ground surface.

The *Wells Regulation* - Where the abandonment barrier is a slurry consisting of clean water and at least 20% bentonite solids by weight, it must be placed using a tremie pipe. The bottom of the tremie pipe must be immersed in the rising accumulation of the abandonment barrier until the required level has been reached.

There are circumstances, such as a very narrow well, that could prevent the use of a tremie pipe as defined by the *Wells Regulation*. As such the *Wells Regulation* allows for the placement of a cement mixture with no more than 5% bentonite solids by weight or bentonite chips or pellets without a tremie pipe in a well that has a diameter less than or equal to 6.5 cm (2.6 inches).

In situations where a tremie pipe is not used, there is a potential for the cement mixture or the bentonite chips or pellets to bridge due to the small diameter of the well. Extreme caution should be exercised for wells deeper than 9 m (30ft) so that the volume of plugging materials added to the well is equivalent to the volume of the well being plugged. Procedures such as pouring slowly, tamping, measuring the material level and measuring the quantity of the material added to the well should be followed [see Step 3(A) in this chapter].

3(C) Well Diameter Greater Than 65 cm (2.1ft) - Dug And Bored Wells

These wells are typically considered shallow dug (i.e., excavated) or deeper bored wells that have large diameter concrete tiles, galvanized steel, hand-lain stone walls or fibreglass casing to support the sides of the well.

Reminder: When determining the diameter of a single casing well, the initial hole diameter at the time of construction must be taken into account in addition to the outer diameter of the casing. The well diameter will determine which well abandonment requirements and procedures are to be followed.

As an alternative to Step 3A in this chapter, a person can plug and seal a well up to approximately 2 metres (6.6ft) below the ground surface using the following sequential method:

i) Filling Materials in Well Screen and Water-Producing Zone

The *Wells Regulation* requires that clean sand or pea gravel be placed from the bottom of the well to the top of the deepest formation supplying groundwater to the well (water producing zone) or to the top of the well screen. The deepest one of the two options must be chosen.

See the following examples:

1. A well record for a deep bored well shows the well was bored through a sand deposit, underlain by a clay deposit and then underlain by a gravel deposit. Both the upper sand and lower gravel deposits supply groundwater to the well. The deepest formation supplying groundwater to the well is the gravel deposit. The clean sand or pea gravel must fill the well from the bottom of the well to the top of the gravel deposit.
2. Where a well screen and a water producing zone are present, the top of the water producing formation is compared to the top of the well screen and the deeper of the two measurements must be used for the location of the top of the clean sand or pea gravel.
3. A intake zone on a bored well is located at the very bottom of the casing. The open bottom of the well allows a large volume of groundwater to enter into the well from the formation. However, the bored well also allows groundwater to enter through the joints between concrete tiles. Unsealed joints in concrete tiles that allow groundwater to enter the well are considered to be well screen (See Chapter 2: Definitions and Clarifications, Table 2-1). In this example, the upper open joint between concrete tiles that is allowing groundwater to enter the well should be considered the top of the well screen. The clean sand or pea gravel must fill the well from the bottom of the well to the top of the joint between the concrete tiles that allows groundwater to enter the well.

If technical information is unavailable for a well such as a deep bored well, further field work or site assessment may be required that could include any of the following:

- Pumping the water level to the bottom of the well and observing where groundwater is entering the well
- Installing a down-hole video camera and viewing the display to observe the interior of the well

- Drilling near the well and making observations
- Conducting a geophysical survey within the well to determine groundwater yielding formations and the location of well screen

ii) Placement of Plugging Materials

The *Wells Regulation* - Plugging materials are required to be placed above the clean sand or pea gravel is required in the well, including the annular space outside any remaining well casing.

Pouring dry plugging material from ground surface is usually sufficient to properly place it in these types of large diameter wells. Any type of slurry materials must be placed using a tremie pipe.

Bentonite Chips and Pellets

The *Wells Regulation* - A 0.1 metre (4 inches) thick layer of sodium bentonite chips or pellets must be placed on top of the sand or pea gravel. The sodium bentonite chips or pellets will begin to hydrate in the water and form a seal.

Well Water Level At or Below the Top of Bentonite Chips or Pellets

The *Wells Regulation* - In some cases, the well water level will be at or below the top of the bentonite chips or pellets that have been placed in the well. If well water is remaining above the bentonite chips or pellets placed in the well, an attempt must be made to pump the well water down to the top of the chips or pellets. If the water level can be pumped down to the top of the chips or pellets or if the water level is already at or below the required level, the following must be done:

- Sodium bentonite powder is mixed with water to create a 20% by weight bentonite slurry as described in Table 15-4 in this chapter.
- A layer of at least 0.3 m (12 inches) of this sodium bentonite slurry mixture is placed on top of the bentonite chips or pellets.
- More bentonite slurry is placed into the well. It should be noted that this material, by itself, does not have sufficient strength to support the weight of humans, animals and vehicles.
- Clean gravel, sand, silt or clay is poured evenly over the sodium bentonite slurry surface to displace the bentonite slurry. The method should allow the materials to mix together.
- If the gravel, sand, silt or clay material rises to within 0.3 m (12 inches) below the top of the bentonite slurry then additional sodium bentonite slurry must be added to ensure that there is always 0.3 m (12 inches) of bentonite slurry at the top during the filling process.
- The process is followed until the well is filled to approximately 2 metres (6.6 feet) below the ground surface.

When Unable to Pump Well Water Down to Bentonite Chips and Pellets

The *Wells Regulation* - In some deeper bored well cases, attempts to pump the well water level down to the top of the bentonite chips and pellets may be unsuccessful. In these cases, the *Wells Regulation* requires sodium bentonite, neat cement or concrete slurries, bentonite pellets or chips, or other materials approved by the Director to be poured or pumped into the well up to about 2 metres (6.6 feet) below the ground surface. Clean sand or pea gravel layers can be placed in any water producing zones.

Strength of Material

The *Wells Regulation* - The plugging abandonment barrier material installed in the well that has a large diameter must have sufficient strength to withstand the weight of humans, animals and vehicles that may move over the area for this alternate method.

4) Removing Entire Casing And Well Screen During Sealing

The *Wells Regulation* - If reasonably possible, the casing and the well screen must be removed (if not already removed in the previous steps) while the bottom of the casing is immersed in the rising accumulation of abandonment barrier material.

In some cases, persons who work at the abandonment of a well are able to lift the casing with equipment including the drill rig while placing the abandonment barrier in a well.

Removing Casing And Well Screen For A Well Constructed With A Driven Point

A point well typically consists of a steel well screen within a steel point and steel risers (casing). In many cases, the point well is placed in sand or other similar formations. These formations are prone to collapse and may be prone to heaving if the casing and steel screened point are pulled from the hole.

Unless exempt, a point well must be properly plugged and sealed in accordance with the nine sequential steps. As the steps are sequential, the casing and well screen must not be removed before the abandonment barrier has been placed into the well.

It is a challenge to pump abandonment barrier material through the interior of the riser and out of the well screen. This will make it difficult to raise the casing while trying to fill the hole with abandonment barrier material.

Depending on the environmental conditions at the site, there may be other methods available to a well contractor for the removal of a shallow point well during proper abandonment. Some examples are as follows:

- If the formation is not prone to heaving, the person who works on the abandonment of the well could use a drill/auger rig with hollow-stem auger flights or temporary casing. The overdrilling method could be used to create an oversized hole to the bottom of the point well. The steel well screen, point and riser(s) (casing) could be removed creating an open hole. The open hole could be filled with an abandonment barrier material. The auger flights or temporary casing, could remain in the hole to hold the hole open. Once the required amount of abandonment barrier has been placed in the open hole, the auger flights or temporary casing can be removed from the hole. When the auger flights or temporary are removed, the abandonment barrier will completely fill the hole.
- The person who works at the abandonment of the well could use a simultaneous jetting and driving method (see the "Jetting and Driving Using a Drop Line and Chisel-Point Bit" section in Chapter 5: Constructing the Hole, Casing & Covering the Well). The equipment could advance a temporary casing adjacent to the existing casing to the bottom of the existing point well. The jetting equipment could be removed from the temporary casing. The temporary casing could be used as a tremie pipe. An abandonment barrier, such as sodium bentonite slurry, could be pumped down the temporary casing. As abandonment barrier is pumped into the hole, the temporary casing, the existing steel well screen, point and riser(s) (casing) could be lifted from the well. The abandonment barrier discharging at the bottom of the temporary casing should fill any open spaces in the existing well and new hole. The bottom of both the original and the temporary casings must be immersed in the rising accumulation of the abandonment barrier during the process.
- The person who works at the abandonment of the well could use a driving machine to drive a temporary casing (drive rod) with an expendable driven point. The equipment could advance the expendable point and temporary casing adjacent to the existing casing to the bottom of the existing point well. The temporary casing could be used as a tremie pipe. An abandonment barrier, such as sodium bentonite slurry, could be pumped down the temporary casing. As abandonment barrier is pumped into the hole, the temporary casing is lifted off the expendable driven point. As further abandonment barrier is pumped, the temporary casing, the existing well screen, point and riser(s) (casing) could be lifted from the well. The abandonment barrier discharging at the bottom of the temporary casing should fill any open spaces in the existing well and new hole. The bottom of both the original and the temporary casing(s) must be immersed in the rising accumulation of the abandonment barrier during the process.

Figure 15-40: Removal Of Well Screen, Point And Riser(s) Using A Jetting Method

The left side of Figure 15-40 shows a cross-sectional diagram of jetting and driving into the ground adjacent to an existing well. The existing well has a casing already in the overburden with a well screen attached to the bottom of the casing and a driven point is on the bottom of the well screen. A cable with a chisel point jetting bit has jetted through the overburden to the same depth as the driven point. Attached to the cable is the water flow and jetting hose that extends down the temporary casing to the chisel point jetting bit. Above the ground a discharge pipe is attached to the temporary casing to enable the discharge of the drilling fluid.

The right side of Figure 15-40 shows a cross-sectional diagram after the jetting hose and chisel point jetting bit have been removed from the temporary casing located adjacent to the existing well. Abandonment barrier material has been pumped through the temporary casing while the existing casing, well screen and casing are raised from the bottom of the well. The abandonment material is typically bentonite slurry and is used to fill the void that remains when the well screen, and casing is removed from the well.

Reminder: This figure is not to scale, it is for illustrative purposes only and does not necessarily represent full compliance with other requirements found in the *Wells Regulation*.

Figure 15-41: Removal Of Well Screen, Point And Riser(s) Using A Driven Method

The left side of Figure 15-41 shows a cross-sectional diagram of an expendable driven point with temporary casing driven into the ground adjacent to an existing well. The existing well has a casing already in the overburden with a well screen attached to the bottom of the casing and a driven point is on the bottom of the well screen. An expendable driven point has been driven through the overburden to the same depth as the driven point.

The right side of Figure 15-41 shows a cross-sectional diagram of the abandonment barrier being pumped through the temporary casing while the original casing, well screen, and driven point are raised. The abandonment barrier material is typically bentonite slury and is used to fill the void that remains when the casing etcetera are removed. The expendable driven point remains in the overburden.

Reminder: This figure is not to scale, it is for illustrative purposes only and does not necessarily represent full compliance with other requirements found in the *Wells Regulation*.

5) Removing At Least Upper 2 Metres Of Casing

The *Wells Regulation* - If reasonably possible and if the casing was not removed under step 2 or step 4, at least two metres (6.6 feet) of casing below the ground surface must be removed (if not already removed in the previous steps) after the abandonment barrier material has been placed in the well. The abandonment barrier material must be placed up to a depth of about 2 metres (6.6 feet) below the ground surface (see Step 3 in this chapter).

A well opening needs to be created to expose the well casing to a minimum depth of two metres below the ground surface prior to its removal. When using an excavator, such as a backhoe or highhoe, a significant hole is created around the well casing. After the hole has been created the person working at the abandonment of the well must take necessary safety measures to cut and remove at least two metres of casing below the ground surface.

Figure 15-42: Removing 2 Metres Of Well Casing

Figure 15-42 shows a licensed well technician removing at least 2 metres (6.6 feet) of well casing from the abandoned well after filling the well with plugging material. Proper safety procedures including shoring and/or sloping the sides of the well opening excavation need to be followed.

Figure 15-43: Cut Casing With Abandonment Barrier

Figure 15-43 shows the top of the casing is cut off. The abandonment barrier material is shown inside the remaining casing and also in the well opening (excavated hole) around the well.

Another method of removing casing is to use a casing cutting device. The device is attached to drilling tools and lowered by the drill machine into the well (see Figure 15-19 and Figure 15-20 in this chapter). The cutting device can easily cut the well casing from the inside at a depth of at least 2 metres (6.6 feet) below the ground surface. Both the casing and the cutting device can be pulled from the well using the drill machine.

Reminder: For large diameter wells (e.g., dug and bored wells), a large excavator is usually needed to lift and remove large concrete tile or galvanized steel casing. During the removal process of large diameter concrete well casing, any broken concrete tiles must be removed from the well before proceeding with further plugging and sealing steps.

In other cases, the upper portion of the well casing may be sealed into bedrock or within a building. In these cases, where removal of the upper two metres of the casing below the ground surface is not reasonably possible, the upper portion of the well casing may be left intact.

Best Management Practice – Removing the Casing

In all cases, the complete removal of casing prior to or during the placement of the abandonment barrier material is the preferred option.

6) When Cement Or Concrete Are Used (This Step Is Only Followed If These Materials Are Used)

The *Wells Regulation* - If the abandonment barrier contains cement, it must set until firm and, if necessary (e.g., if it settles out into the formation), it must be topped up to approximately 2 metres (6.6 feet) below the ground surface.

7) Removing Below Ground Concrete Structures And Slabs

The *Wells Regulation* - Well pits, structures and slabs are sometimes removed before the well is plugged during step 2. However, this can also be done during the abandonment process at any time before the sealing of the upper 2 m (6.6 feet) of the well opening. Any below ground concrete structures, foundations and slabs must be removed unless the remaining structures (e.g., a building) become destabilized, damaged or unsafe when the underground slabs or structures are removed.

The structures must be removed to at least a depth adequate to accommodate the sealing measures.

Best Management Practice – Sealing and Decommissioning any Waterlines and Related Equipment

It is important to properly seal and decommission any waterlines and related equipment (e.g., a large diameter conduit that surrounds the waterline) that extend underground from a well to a building. If not properly decommissioned, the underground waterline and related equipment may act as a pathways for surface water and other foreign materials to gain access to the building, or to flow toward the area of the abandoned well.

8) Plugging And Sealing The Upper 2 Metres(6.6 feet) Of The Well Opening

The *Wells Regulation* - To prevent inadvertent or unauthorized access, the well and the well opening (which includes any excavation) must be sealed up to the ground surface by:

- placing 50 cm (1.6 ft) to 150 cm (5 ft) in vertical thickness of bentonite chips, pellets, granules or powder in accordance with the manufacturer's specifications, and
- filling the remaining well and well opening above the layer of bentonite and up to the ground surface with soil cover or other material that is more in keeping with the existing material immediately adjacent to the well opening.

Best Management Practice – Placing Bentonite Chips, Pellets, Granules or Powder

When placing manufactured bentonite chips, pellets, granules or powder in the well opening, they should be fully hydrated to ensure bentonite is fully expanded and prevent any future up-heaving of the ground surface. Care should be taken to estimate the depth of bentonite needed in the well opening by taking into account the significant expansion of bentonite after hydration.

As each environment is unique, the thickness and type of bentonite and the placement method used to fill the well opening should be determined on a case by case basis to ensure that the thickness remains in the required range after filling the well opening. These considerations are important to prevent any collapse at the well opening if a vehicle, animal or human passes over the abandoned well and to offer the best protection to the environment.

Figure 15-44: Placing Bentonite Pellets On Top Of Abandonment Barrier

Figure 15-44 shows bentonite pellets being placed in the well opening (excavation) on top of abandonment barrier material (bentonite) in a drilled well (see Figure 15-43). Bentonite pellets need to fill the entire well opening and be at least 50 cm (1.6ft) to 150 cm (5ft) thick.

9) Stabilizing Disturbed Area

The *Wells Regulation* - The area of the ground surface where the well is located must be covered and stabilized to prevent any erosion.

For example, this can be achieved by seeding grass or sodding the area of the filled well opening on a golf course or lawn.

Best Management Practice – Filling and Stabilizing Well Opening

It is important to make sure the material placed in the well opening has sufficient strength to hold the weight of humans, animals and vehicles.

Diagrams Of Plugged And Sealed Wells

Figure 15-45 to Figure 15-48 provide examples of various well types that have been plugged and sealed based on the nine step sequential process.

Reminder: All figures and diagrams are not to scale, are for illustrative purposes only and do not necessarily represent full compliance with other requirements found in the *Wells Regulation*.

Figure 15-45: Plugging And Sealing Wells ≥ 6.5 cm (2.5 inches)

Figure 15-45 is a cross section diagram of two methods of plugging and sealing wells that are greater than 6.5 centimetre in diameter. The example on the left shows the well casing completely removed. The example on the right shows that only 2 metres of casing has been removed from the top of the well.

In the example on the left, an abandonment barrier has been placed in the clay layer to plug and seal the well from the water producing zone below. The clay is a natural barrier stopping any water from moving sideways. Clean, washed sand or gravel is placed on top of the abandonment layer to match the gravel aquifer conditions found above the clay layer. Another layer of abandonment barrier topped with bentonite chips, pellets, granules or powder and a final stabilized soil cover is used to cap the well.

In the example on the right, only the top 2 metres of the casing has been removed so from the top of the remaining casing, all the way down to water producing layer, an abandonment barrier is placed inside the well. On top of this barrier bentonite chips, pellets, granules or powder are used with a final stabilized soil cover employed to cap the well.

- This procedure is typically used for drilled wells and may also be used for direct push, dug and bored wells. It is permitted for any type of well with a diameter greater than 6.5 cm (2.5 inches).
- Abandonment barrier slurries must be placed using a tremie pipe.
- Abandonment barrier must prevent any movement of water, natural gas, contaminants or other materials between subsurface formations (including aquifers) and between a subsurface formation (including an aquifer) and the top of the abandonment barrier.
- Water should be added to the bentonite chips, pellets, granules or powder to start hydration.
- Soil cover can be other material in keeping with existing adjucent surface material. The soil cover must prevent inadvertent and unauthorized access.
- Well opening is typically excavated to remove the top portion of the well casing.

Reminder: This figure applies to situations where narrow diameter wells (≤ 6.5 cm) are overdrilled to a diameter ≥ 6.5 cm. It also applies to wells with a diameter ≥ 6.5 cm that are constructed with flush-mounted well pits (vaults).

Reminder: The diagram above is not to scale, it is for illustrative purposes for this chapter only and it does not necessarily represent full compliance with other requirements found in the *Wells Regulation*.

Figure 15-46: Plugging And Sealing Narrow Diameter Wells ≤ 6.5 cm (2.5 inches)

Figure 15-46 is a cross section diagram showing the method to be used where well casing and well screen are being removed or are absent. An abandonment barrier, made up of Portland cement and up to 5% bentonite solids by weight, or, if a tremie pipe is used then clean water and at least 20% bentonite solids by weight, is placed in the well down to the bottom of the well. On top of the abandonment barrier, bentonite chips, pellets, granules or powder are placed and stabilized cover soil is placed over the entire operation.

- This is for situations where well casing and well screen are being removed or are absent.
- This is typically for narrow diameter drilled, jetted and driven point wells
- Abandonment barrier must prevent any movement of water, natural gas, contaminatnts or other materials between subsurface formations (including aquifers), and between a subsurface formations (including and aquifer), and the top of the abandonment barrier
- Water should be added to the bentonite chips, pellets, granules or powder to start hydration
- If well casing and screen are not being removed, the abandonment barrier must be:
  - A slurry of clean water and Portland cement + up to 5% bentonite solids by weight, or
  - Bentonite chips or pellets that have been screened and placed in accordance with manufacturer's specifications.

  At least the top 2m (6.6ft) of the casing must be removed, if reasonably possible.

- Well opening is typically excavated to remove the top portion of the well casing.

Reminder: This figure and associated notes apply to situations where narrow diameter wells (≤ 6.5 cm) are constructed with flush-mounted well pits (vaults) and the casing and well screen have been removed.

Reminder: The diagram above is not to scale, it is for illustrative purposes for this chapter only and it does not necessarily represent full compliance with other requirements found in the *Wells Regulation*.

Figure 15-47: Plugging And Sealing Large Diameter Wells ≥ 65 cm (2.5ft) - Alternate Methods

Figure 15-47 is a cross sectional diagrams showing two examples of how to plug and seal large diameter wells. The diagram A on the left shows the method to use when the water level in the well can be drawn down to the water table. A 4 inch layer of bentonite chips is put down the well and sits on top of clean sand or pea gravel from the bottom of the well. A bentonite slurry is placed inside the casing up to the well opening. 1 inch of bentonite slurry is placed above this layer in the excavated opening above the well opening. A 1.6 inch to 5 inch layer of bentonite chips, pellets, granules or powder is placed on top of the bentonite slurry. Stabilized soil is then placed on top to match the level of the surrounding ground cover.

The Diagram B on the right shows the method to use when the water level in the well cannot be drawn down to the water table. A 4 inch layer of bentonite chips is put down the wells and sits on top of the clean sand or pea gravel from the bottom of the well. An abandonment barrier is interspersed with clean sand or pea gravel in the water producing zone of the well up to the casing opening. A 1.6 inch to 5 inch layer of bentonite chips, pellets, granules or powder is placed on top of the well opening in the excavated opening above the well opening. Stabilized soil is then placed on top to match the level of the surrounding ground cover.

- This alternate method is typically large diameter dug, bored or augered wells.
- Abandonment barrier slurries must be placed using a tremie pipe.
- Soil cover can be other material in keeping with existing adjacent surface material. The soil cover must prevent inadvertent and unauthorized access.
- Abandonment barrier must prevent any movement of water, natural gas, contaminatnts or other materials between subsurface formations (including aquifers), and between a subsurface formation (including an aquifer), and the top of the abandonment barrier.
- Water should be added to the bentonite chips, pellets, granules or powder to start hydration.
- Well opening is typically excavated to remove the top portion of the well casing.

Reminder: The well in Diagram 'A' of Figure 15-47, above, is filled with a bentonite slurry (minimum 20% bentonite solids by weight) + clean gravel, sand, silt or clay. In this case, the placement method is important. See the placement method in step 3(C) in this Chapter.

Reminder: The diagram above is not to scale, it is for illustrative purposes for this chapter only, and it does not necessarily represent full compliance with other requirements found in the *Wells Regulation*.

Figure 15-48: Plugging And Sealing A Drilled Well Through A Large Diameter Dug Well Or Well Pit

Figure 15-48 is a cross sectional diagram of a drilled well that has been drilled through fractured bedrock and has been plugged and sealed. An abandonment layer has been placed at the bottom of the well. Above this layer is a layer of clean sand or pea gravel. Above this layer is another layer of abandonment barrier. Above this layer is a layer of clean sand or pea gravel. At the water table level, a 4 inch layer of bentonite chips or pellets has been placed. Above this layer is a bentonite layer with minimum 20% solids and clean gravel, sand, silt or clay. Above this layer is 1 inch of bentonite layer with a minimum of 20% solids by weight. Above this layer is a 1.6 inch to 5 inch layer of bentonite chips, pellets, granules or powder. Stabilized soil tops all the layers and is level with the ground service.

- Requirments for wells ≥ 6.5 cm (2.5 inches) apply to the drilled portion of the well, and alternate method for wells ≥ 65 cm (2.5ft) could be used from the bottom of the dug well or well pit up to the ground surface.
- Abandonment barrier slurries must be placed using a tremie pipe.
- Soil cover can be other amterial in keeping with existing adjusting surface material.
- The abandonment barrier must be prevent any movement of water, natural gas, contaminnants or other materials between subsurface formations (including aquifers) and between a subsurface formation (including an aquifer), and the top of the abandonment barrier.
- Water should be added to the bentonite chips, pellets, granules or powder to start hydration.
- Well opening is typically excavated to remove the top portion of well casing.

Reminder: If water cannot be pumped down to the top of the 0.1 m (4 inches) of bentonite chips or pellets see Figure 15-47(B) and step 3(C) in this chapter for material placement method. If present, a well pit floor made of suitable sealant must be removed in this case to allow for the placement of clean sand or pea gravel.

Reminder: The diagram above is not to scale, it is for illustrative purposes for this chapter only, and it does not necessarily represent full compliance with other requirements found in the *Wells Regulation*.

Abandonment Of Flowing Wells

Where flowing wells cannot be properly controlled or stopped during well construction, they must be properly abandoned. In these cases, the person abandoning the well must ensure that the person who works at the abandonment of the well properly plugs and seals the well to prevent the movement of the free flowing water. Properly plugging and sealing the well should restore the aquifer to its original condition (i.e., prior to the construction of the well).

The *Wells Regulation* - The cost associated with the abandonment is to be absorbed by the well contractor unless a previously established written contract expressly releases the well contractor from the cost.

Reminder: Only licensed well contractors and well technicians with experience in flowing wells should attempt to plug flowing wells.

If Flow At Surface Can Be Controlled Using Weighted Fluids

The flow at the surface from the aquifer can be controlled using weighted fluids (muds). Weighted drilling fluids include bentonite based drilling muds with barite additives. Once the flow is controlled using weighted drilling fluids, the abandonment can usually be successfully carried out using a high specific gravity cement based grout such as a neat cement or concrete. In many cases, the casing needs to be removed to expose the upper portion of the water producing zone. This will allow for the concrete or cement to more effectively seal the hole and fill any cavities that may have formed around the outside of the well casing, and restore the aquifer to its original condition.

The downhole hydrostatic head pressure and downward grout pressure need to be calculated to determine the density and type of material (e.g., concrete) needed to stop the flow of groundwater from the aquifer (see Chapter 12: Flowing Wells for additional information). This abandonment barrier must be placed upward from the bottom of the well using a tremie pipe.

The *Wells Regulation* - If the well is a flowing well, commercially manufactured drilling mud may be used to assist with drilling or the placement of an abandonment barrier. The drilling mud must not impair the quality of the water that it comes into contact with and it is not allowed to be used as an abandonment barrier.

Only licensed well contractors and well technicians with experience in flowing well construction should attempt to plug flowing wells.

If Flow At Surface Cannot Be Controlled Using Weighted Grouts

If it is not possible to control the flow using weighted grouts, then it may be necessary to offset and drill a properly constructed depressurization (relief) well or wells. These relief wells must be constructed and pumped to reduce the flowing head conditions at the encountered well. Once the flowing conditions are controlled, proper abandonment of the flowing well can proceed. However, extreme caution must be used when constructing the relief wells as there have been many cases where the relief wells did not work or became problem flowing wells themselves. The relief wells would then have to be properly abandoned.

In some cases other techniques have successfully been used to temporarily stop the flow of water from the well to allow for the placement of abandonment material. These include: raising the casing above the static water level and freezing with liquid nitrogen to temporarily seal the aquifer around the well.

Best Management Practice – Retaining Professional Expertise

The person abandoning the well should consider retaining a Professional Geoscientist or Professional Engineer to determine the type of abandonment barrier materials to use in the abandonment of the flowing well and to prepare a design to plug and seal the flowing well.

Figure 15-49 to Figure 15-54 show the specialized equipment and materials necessary to seal a high pressure flowing well to protect property, surface water and prevent adverse effects on the natural environment.

Figure 15-49: Flowing Well AT Back Of Drilling Rig

Figure 15-49 shows the casing of the drilled well extending just above the ground surface behind the drill rig. The drill rods are attached to the drill rig and extend down into the well casing. In this case, the well is approximately 21 m (69ft) deep. Groundwater and drilling mud are flowing from the working casing to a horizontal pipe and discharging into a tank. Flowing water from the well cannot be stopped and is freely flowing into the tank with the drilling mud. The discharged material and water are directed into a prepared and

approved sediment discharge and settling area on the site. In this case, the well driller could not stop the high pressure of the flowing groundwater out of the well with a weighted drilling mud and had to abandon the well (see Figure 15-50 to Figure 15-54).

Figure 15-50: Attaching Tremie Pipe To Truck

In Figure 15-50 and Figure 15-51, the consultants and drillers determined the best way to seal this high pressure flowing well was to remove nearly all of the well casing in the well. The consultant calculated that 3.5 m (11.5ft) of concrete would supply sufficient weight to overcome the downhole hydrostatic head pressure and stop the flow. The consultant also determined a high pressure specialized cement pump truck would be necessary to pump the concrete at a high rate into the hole to ensure the material's weight would quickly overcome the groundwater's downhole hydrostatic head pressure. Figure 15-50 shows the persons working on the abandoned well attaching the top of the tremie pipe to the cement pump truck (on left side of photograph).

Figure 15-51: Tremie Pipe Going Into Flowing Well

Figure 15-51 shows the tremie pipe (behind the drill rig) going into the flowing well from Figure 15-49. The bottom of the tremie pipe was installed near the bottom of the well. In the background, a cement truck with more than the calculated volume of concrete and cement pump truck are standing by to start the pumping operation.

Figure 15-52: Concrete Pumping Operation

Figure 15-52 shows the cement pump truck with its boom in the air and over the drill rig almost prepared for the pumping of concrete into the flowing well from Figure 15-49. The cement truck is backing up to the cement pump truck to begin the plugging operation.

Figure 15-53: Pumping Concrete

Figure 15-53 shows the concrete being pumped at a high rate into the flowing well from Figure 15-49. The concrete is displacing the remaining water in the well. The water is discharging from the well onto the surface and into a controlled sediment settling area. The consultant and well owner had obtained a Permit to Take Water since the flowing well was discharging at a rate greater than 50,000 litres per day.

Figure 15-54: Flow Stopped

Figure 15-54 shows that the placement of 3.5 cubic metres (123.6 cubic ft) of concrete within a few minutes has stopped the flow of water out of the well. The aquifer has been sealed and restored to its original state. The concrete will cure and act as a permanent seal. The entire well casing was removed exposing the open hole at surface. The upper portion of the well opening will be properly plugged.

Wells Within Larger Diameter Wells Or Well Pits

When a well is to be abandoned, the *Wells Regulation* requires the filling, plugging and sealing of the entire well. Different materials and filling procedures apply to wells of different diameters.

In some cases, drilled wells were installed through dug or bored wells. The drilled wells are typically small diameter wells and the dug or bored wells have diameters greater than 65 cm (26 inches).

In other cases, drilled wells are installed in well pits. For the purpose of well abandonment, well pits are considered wells and must be properly plugged and sealed as outlined in this chapter. When considering the type of abandonment barrier to be installed in the well, the:

- the portion of the well inside the well pit (less than or equal to 65 cm (26 inches)) must be plugged with abandonment barrier in accordance with step 3 (A) or 3(B) in this chapter depending on the diameter of the well, up to about 2 m (6.6ft) below the ground surface; and
- the large diameter portion of the dug well or well pit must be sealed in accordance with step 3(A), or as an alternative Step, 3 (C) in this chapter up to about 2 m (6.6ft) below the ground surface.

For a well with a well pit, which is less than 65 cm (26 inches) in diameter the following abandonment barrier requirements apply:

- the portion of the well inside the well pit [less than or equal to 65 cm (26 inches)] must be plugged with abandonment barrier in accordance with step 3(A) or step 3(B) in this chapter, depending on the diameter of well, up to about two metres below the ground surface.

With respect to the removal of both large and small diameter casings, a person must follow Steps 2, 4 and 5 of the nine sequential steps to plug and seal a well.

The person abandoning the well must then ensure the remaining steps (6 to 9) to complete the filling, plugging and sealing of the abandoned well. This includes:

- placing 0.5 m (1.6ft) to 1.5 m (5ft) bentonite chips, pellets or granules in the upper 2 m of the well, and
- filling the remaining portion of the well to ground surface with soil cover or other material that is more in keeping with the existing material immediately adjacent to the well opening. Examples of other material can include:
  - concrete for wells within buildings or on sidewalks, or
  - asphalt for wells on roads.

Reminder: There are many cases of existing wells housed in well pits. Over time, some of these pits may allow contaminants and/or surface water to enter well and may cause groundwater mounding. For improved maintenance and sanitary protection, some wells are being altered to extend the top of the well casing above the ground surface and the well pits are being plugged and sealed. If the well owner decides to continue to use the well, with the new casing extension, and to abandon the well pit:

- the person abandoning the well pit portion of the well must ensure the well pit is abandoned, with necessary modifications, as if it were a well, and
- the person constructing (altering) the well and the well owner should review the information found in the section titled: “Extension of Well Casing for a Well in a Well Pit,” in Chapter 11: Maintenance & Repair.

Reminder: For examples of properly abandoned wells in well pits, refer to Figure 15-48.

Excavating The Entire Well

If a well is abandoned by excavating the entire well in the course of work carried out for another purpose, then the person abandoning the well, often the well owner, does not need to ensure that the well is abandoned in accordance with the nine step sequential process. In this case, the person abandoning the well, often the well owner, must ensure that:

- the “Obligation to Retain a Licensed Well Contractor” or the “Exemption - Obligation to Retain a Licensed Well Contractor” sections in Chapter 3: Well Contractors & Well Technicians – Licences, Responsibilities & Exemptions are followed,
- the well tag, if present, is returned to the Director within 30 days after its removal, and
- unless exempt, a well record is completed and submitted as described in Chapter 13: Well Records, Documentation, Reporting & Tagging.

Reminder: A person can abandon a well before it is completely excavated. In this case, the person abandoning the well, often the well owner, must ensure that:

- the “Obligation to Retain a Licensed Well Contractor” or the “Exemption - Obligation to Retain a Licensed Well Contractor” sections in Chapter 3: Well Contractors & Well Technicians – Licences, Responsibilities & Exemptions are followed,
- the well is abandoned following the nine sequential step approach described in this chapter, and
- unless exempt, a well record is completed and submitted as described in Chapter 13: Well Records, Documentation, Reporting & Tagging.

Work carried out for another purpose that involves the entire removal of the well by excavation could include any of the following:

- Installing a new building foundation
- Excavating elevator shafts
- Removing overburden and other materials that are on a contaminated site
- Excavating to create a pond, trench or lagoon
- Excavating in an open pit mine, quarry or sand and gravel pit

Reminder: A plan for development at a site that may excavate an entire well in the future does not exempt the well owner from the requirement to immediately abandon a well that is not being used or maintained for future use as a well. In these cases, the person abandoning the well must follow the nine (9) sequential steps to plug and seal the well and not wait until the future excavation occurs.

After The Well Is Plugged And Sealed

1) Completing And Submitting A Well Record

The person abandoning the well (often the well owner) must obtain a blank well record form from the Ministry of the Environment and Climate Change. An explanation of who is considered the person abandoning the well is found in the "Plainly Stated" section in this chapter.

The *Wells Regulation* - On completion of the abandonment of a well, the person abandoning the well, often the well owner, must:

- within 14 days after the date on which the well construction equipment is removed from the site, deliver a copy of the well record to the owner of the land on which the well is situated; and
- within 30 days after the date on which the well construction equipment is removed from the site, forward a copy of the well record and any well tag that was removed from the well, to the Director.

Reminder: The person working at the abandonment of a well can assist the person abandoning the well, often the well owner, in completing the well record and delivering the well record to the Ministry (see Chapter 13: Well Records, Documentation, Reporting & Tagging for additional information on the well record).

Best Management Practice – Attaching Written Approval to Well Record

If an alternative abandonment barrier has been approved by the Director and installed in the well, the person abandoning the well should attach the original written approval to the Ministry's copy of the well record and submit a copy of both the record and written approval to the Ministry within the required timeframe. The original written approval should be kept by the owner of the land along with the well record. The person working at the abandonment of the well should retain a copy of the written approval with the well record for future reference.

2) Providing Important Information To The Well Owner

After the well has been plugged and sealed the following key information should be provided to the well owner:

- Additional maintenance (e.g., landscaping) may be required because the topsoil layer or other material at the surface might settle immediately after the abandonment or later
- Relevant safety issues, such as avoiding any digging on or around the plugged and sealed well. For example, if the plugging material in a flowing well is accidentally hit by a large excavating machine, the seal may be compromised and allow water to flow up to the ground surface potentially creating adverse effects (e.g., flooding, property damage)
- The importance of the well abandonment information on the well record for future reference (e.g., location, abandonment details) and the importance of providing future land purchasers with this documentation

Best Management Practice – Maintaining Area to Prevent Erosion

It is important that the owner of the land maintain the ground surface around the plugged and sealed well to prevent any erosion.

Best Management Practice – Recommending that the Well Owner Make Extra Copies of Well Record

It is recommended that the well owner make additional copies of the well record and keep the copies in a location where they can be easily found such as one or more of the following:

- Beside the pumping equipment
- With mortgage papers
- With land property survey
- In a safety deposit box
- Properly filed at the business' head office

Best Management Practice – Transferring a Well Record to a New Well Owner

The well owner should provide copies of all well records for wells, including the abandoned wells, when the property is transferred to a new owner. The new well owner will then have knowledge of the location and status of the wells on the property to prevent:

- well damage from any new excavations or building on the property, and
- well contamination from any new source of contaminants constructed near a well.

Who Can Be Contacted For Information Or Assistance?

The local Ministry of the Environment and Climate Change office can be found in the Resources section of this manual or in the telephone book. The local environmental officer should be able to answer questions or provide other contacts with Ministry experts on wells. The Ministry's wells articles on the Ontario website also provide information on water and water wells and a link to the Wells Help Desk.

Licensed well contractors (e.g., drilling, excavating and pump installation) can be found in the telephone book or on the internet under water well drilling and services. The Ministry maintains an online database of licensed well contractor.

Professional Geoscientists or Professional Engineers can be found in the telephone book or on the internet under Environmental Consultants or on the Association of Professional Geoscientists of Ontario website or Professional Engineers Ontario website.

Is There Funding Available For Private Well Owners?

In some cases, provincial funding may be available to pay for a portion of the well abandonment costs. If funding is available, it is usually distributed through the local conservation authority. A local conservation authority can be found in the blue pages of the telephone book or on the internet at the Conservation Authority contact list webpage.

16. Glossary

Some of the terms in this Glossary are borrowed with permission from the following sources:

- GWW = Groundwater and Wells: Third Edition. 2007. Robert J. Sterrett (editor). Johnson Screens/a Weatherford Company. New Brighton, Minnesota. Glossary (Pp. 753-774)
- NGWA Inc. = Illustrated Glossary of Driller's Terms. 2004. National Ground Water Association Inc., Westerville, Ohio
- ASTM D5092 = Standard Practice for Design and Installation of Ground Water Monitoring Wells. ASTM International, West Conshohocken, PA.
- Gowen = Gowen Environmental Ltd. – Online Glossary

Acid
: Any chemical compound containing hydrogen capable of being replaced by positive elements or radicals to form salts. In terms of the dissociation theory, it is a compound which, on dissociation in solution, yields excess hydrogen ions. Acids lower the pH. Examples of acids or acidic substances are hydrochloric acid, tannic acid, and sodium acid pyrophosphate.(GWW)

Aggregate
: Granular mineral or rock material (e.g, sand, gravel) that is mixed with cement to form concrete.(Gowen)

Air Vacuum Value
: A relief valve designed to allow air to enter into and vent from a water system at a high volume. When water encounters the valve, a weighted ball seals to a plate in the valve and creates a watertight seal.

Air Release Valve
: A relief valve designed to allow gases (that build up in the water column) to slowly vent from the water column. When water encounters the valve, a weighted ball seals to a plate in the valve and creates a watertight seal.

Air Lift
: To lift water or drilling fluid to the ground surface by pushing high velocity compressed air through the drilling stem. (GWW/NGWA)

Alkaline
: Any of various soluble mineral salts found in natural water and arid soils having a pH greater than 7. In water analysis, it represents the carbonates, bicarbonates, hydroxides, and occasionally the borates, silicates, and phosphates in the water.(GWW)

Aquiclude

An outdated term for a geologic layer of very low permeability located so that it forms an upper or lower boundary to a groundwater flow system. Aquitard or Confining Layer are preferred terms.(Gowen)

Aquifer Test
: A test which involves adding to or discharging measured quantities of water from a well, and recording the resulting changes in head in the aquifer (during and after addition/withdrawal). Examples are slug tests, bail tests and pumping tests.(Gowen)

Aquitard
: A geological formation that may contain groundwater but it is not capable of transmitting significant quantities of groundwater under normal hydraulic gradients (e.g. clay layers). In some situations aquitards may function as confining beds.(Gowen)

Artesian
: The condition of water in a confined aquifer being under sufficient pressure that the potentiometric surface is above the bottom of the overlying confining bed. The water level within a well in an artesian (or confined) aquifer rises to a point above the bottom of the confining bed that overlies the aquifer. It is not necessary for the water to flow at ground surface. If the water is under enough pressure, the potentiometric surface may be above the ground surface. In this case, water may actually flow from the well without pumping. Such a well is a flowing artesian well (or flowing well).(Gowen)

Artesian Aquifer
: See Confined Aquifer

Backfill
: Material used temporarily during construction or permanently to replace material being removed.(Gowen)

Backwashing (Well Development)
: A well development technique that uses surging or reversal of water flow in a well. The procedure removes fine material from the formation surrounding the well screen which can enhance well yield.

Bacteria
: Unicellular microorganisms that exist as free living organisms or as parasites and have a broad range of biochemical, and often pathogenic, properties.(Gowen)

Bactericide
: A substance that destroys bacteria.(Gowen)

Bailing
: To remove sediment, water, drill cuttings or other debris from a well or borehole with a bailer.(GWW/NGWA)

Bailer
: A cylinder (or tube) suspended from a cable or rope to remove sediment, drill cuttings, water or other material from a well. A bailer has an open top and a check valve at the bottom. Bailers such as dart valve or flapper valve bailers can be large and operated from a drilling rig. Other bailers used to sample water are small enough to be hand held.

Bail Test(Rising Head Test)
: An aquifer test carried out to determine in-situ hydraulic conductivity by instantaneously removing a known volume of water from a well and measuring the resulting water level recovery in the well.(Gowen)

Ball Valve
: A valve regulated by the position of a free-floating ball that moves in response to fluid or mechanical pressure.(Gowen)

Barite
: Natural finely ground barium sulfate used for increasing the density of drilling fluids.(GWW)

Bentonite Granules And Chips
: Irregularly shaped particles of bentonite (free from additives) that have been dried and separated into a specific size range.(ASTM D5092) For further information on bentonite see Table 2-1 of Chapter 2: Definitions & Clarifications.

Bentonite Pellets
: Roughly spherical shaped or disc shaped units of compressed bentonite powder that may be coated with some chemicals.(ASTM D5092) For further information on bentonite see Table 2-1 of Chapter 2: Definitions & Clarifications.

Bit(Drill Bit)
: The cutting tool attached to the base or bottom end of the drill string that breaks the formation into smaller pieces (cuttings) during drilling. Its design varies according to the type of formation and drilling equipment used.(GWW/NGWA)

Blowout
: An uncontrolled escape of drilling fluid, gas, oil or water from the well, caused by the formation pressure being greater than the hydrostatic head of the fluid in the hole.(GWW)

Borehole
: An open or uncased subsurface hole that is circular in plan view. The borehole is typically drilled, augered or bored into the earth. (ASTM D5092)

Breathing Well (Sucking & Blowing)
: Conditions where the well and aquifer formation are significantly affected by changes in atmospheric pressure which can cause the periodic suction and expulsion of gases. Sucking and blowing (breathing) wells have been linked to the accumulation of gases low in oxygen in well pits leading to asphyxia.

Bridge

Conditions where the well and aquifer formation are significantly affected by changes in atmospheric pressure which can cause the periodic suction and expulsion of gases. Sucking and blowing (breathing) wells have been linked to the accumulation of gases low in oxygen in well pits leading to asphyxia.(GWW/NGWA - modified)

Bulk Density

The amount of mass of a soil per unit volume of soil; where mass is measured after all water has been extracted and the total volume includes the volume of the soil itself and the volume of the air space (voids) between the soil grains.(Gowen)

Casing Driver

A device fitted to the tophead drive of a direct rotary rig's mast. It allows the casing to be advanced during drilling but allows the drilling and driving to be adjusted independently.(GWW)

Casing Jacks

Hydraulic jacks used to pull casing or the drill stem from the well.(GWW/NGWA)

Casing Rotator

A device installed on a drilling rig that clamps around the casing. Once the rotator clamps onto the casing, the rotator can be rotated clockwise or counter clockwise into the ground. It also can adjust the distance between the casing and the drilling bit.(GWW)

Caving (Sloughing)

The inflow of unconsolidated material into a borehole that occurs when the borehole walls lose their cohesiveness.(ASTM D5092)

Cavitation

A phenomena of cavity formation, or formation and collapse, especially in regard to pumps, when the absolute pressure within the water reaches the vapour pressure, causing the formation of vapour pockets.(GWW)

Cement

(Portland Cement) – A mixture that consists of calcareous, argillaceous, or other silica, alumina-, and iron-oxide-bearing materials that is manufactured and formulated to produce various types which are defined in Specification ASTM standard C 150 Specification for Portland Cement.(ASTM D5092)

Centralizer

A device that assists in the centering of a casing or well screen within a borehole or another casing.(ASTM D5092)

Centrifugal Pump

A pumping mechanism that spins water by means of an “impeller”. Water is pushed out by centrifugal force. Centrifugal deep-well jet pumps work with two lines into the well. As water is moved at the surface by an impeller, some of the water is returned to the well to the ejector assembly above the intake. This return water creates a “venturi” effect in the ejector, sucking well water through the check valve.

Check Valve

A mechanical device which normally allows a fluid or gas to flow through it in only one direction. There are various types of check valves for various needs. Check valves typically work automatically. An important concept in a check valve is the cracking pressure which is the minimum upstream pressure at which the valve will operate. Thus, the check valve is designed for a specific cracking pressure.

Collar(Stabilizer)

A length of extremely heavy steel tube used in well drilling. It is placed in the drill string immediately above the drill bit to minimize bending, maintain plumbness, and provide weight on the drill bit while drilling.(GWW/NGWA)

Cone Of Depression

The area around a discharging well where the hydraulic head (potentiometric surface) in the aquifer has been lowered by the pumping. In an unconfined aquifer, the cone of depression is a cone-shaped depression in the water table where the formation has actually been dewatered.(Gowen)

Confined Aquifer (Artesian Aquifer)

A fully saturated aquifer overlain by a confining layer. The potentiometric surface (hydraulic head) of the water in a confined aquifer is at an elevation that is equal to or higher than the base of the overlying confining layer. Discharging wells in a confined aquifer lower the potentiometric surface which forms a cone of depression, but the saturated formation is not dewatered.(Gowen)

Confining Bed(Unit)

A geologic bed of impermeable (or very low permeable) material stratigraphically adjacent to one or more aquifers. Confining bed is commonly used to replace terms such as aquiclude, aquitard and aquifuge.(Gowen)

Confining Layer

A geologic body of low hydraulic conductivity above or below one or more aquifers. Confining layer is commonly used to replace the term aquiclude.(Gowen)

Consolidated Formations

Geologic formations of natural material that has been lithified. The lithification creates a material with high strength and resistance to disintegration.(Gowen)

Corrosion

The act or process of dissolving or wearing away metals.(GWW)

Cuttings (Drill Cuttings)

Fragments of soil or rock created by the drilling process with or without a drilling fluid (e.g, water).(Gowen)

Density

The amount of mass per unit volume.(Gowen)

Dewatering

Removing or draining water to lower the water table or potentiometric surface (e.g. by pumping a well or letting groundwater flow from a flowing well). Dewatering is commonly done during construction activities and to keep underground structures dry.

Discharge Area

An area in which there is upward groundwater flow in the subsurface. Groundwater flows toward the surface in a discharge area and may escape as a spring, seep or baseflow. A discharge area can also be an area where water, heavily chlorinated water or other material is discharged from a well.(Gowen)

Downgradient

A downward hydrologic slope that causes groundwater to move toward lower elevations. Wells downgradient of a source of contamination are prone to receiving the contaminant's parameters at elevated concentrations.(Gowen)

Drawdown

A lowering of the water table in an unconfined aquifer or the potentiometic surface of a confined aquifer caused by the pumping of groundwater from a well.(Gowen) The difference between the static water level (SWL) and the pumping water level (PWL) in a well. Drawdown = PWL – SWL.

Drill Bit

See Bit.

Drill Collar

See Collar.

Drill Cutting

See Cuttings.

Drill Hole

See borehole.

Drill Rod (Pipe)

Special hollow jointed or coupled rods (pipes) that are used in creating a drill string from the rotating mechanism (typically with the drilling rig) to the bit.(Gowen)

Drill String

The string includes the drill rods (pipes) attached from the rotating mechanism to the collar, the collar and the bit. The drill string is used to transmit rotation from the rotating mechanism (typically with the drilling rig) to the bit. The drill string conveys air or drilling fluid which removes cuttings from the borehole and cools the bit.

Drilling Fluid

A water, bentonite-water or air-based fluid used in well drilling to remove cuttings from the hole, to clean and cool the bit, to reduce friction between the drill string and the sides of the hole, and to seal the borehole. When a bentonite-water mixture is used it is sometimes called mud or drilling mud.

Drive Shoe

A forged steel collar on the bottom of a casing. The collar has a cutting edge to shear off irregularities in the hole as it advances. A drive shoe is considered casing and is used to form a seal between the casing and the bedrock.(Gowen)

Drop Pipe

The pipe (riser pipe or waterline) that carries water from a pump in a well (or from a foot valve) up to the surface through the top of the well or to a pitless adapter. The drop pipe is considered to be part of a pump as defined by the *Wells Regulation*.

Dry Weight

The weight of a sample based on % solids. The weight after drying in an oven.(Gowen)

Dual Porosity

A subsurface formation in which groundwater flow occurs through fractures and through pore space. For example, in a fractured till, groundwater can flow through the fractures and through the pore space among the till particles.(Gowen)

Effective Hydraulic Diameter

The area in which water from the aquifer can move freely into a well. If a well is completed with a well screen and surrounded by filter pack material, the effective hydraulic diameter is equal to the diameter of the borehole.

Effective Porosity

The amount of interconnected pore space through which fluids can pass. Effective porosity is usually less than total porosity because some pores may be occupied by static fluid.(Gowen)

Equilbrium

Condition that exists in a system when the system does not undergo any change of properties with the passage of time. Typically multiple forces produce a steady state (balance) resulting in no change over time.(Gowen)

Erosion

The general process whereby the materials of the earth's crust are moved from one place to another by running water (including rainfall), waves and currents, glacier ice, or wind.(Gowen)

Filter Pack

A filter pack is a well sorted gravel or coarse sand that can be:

- Developed around the well screen (naturally developed from native granular material);
- Selected and placed into the hole surrounding the well screen and developed (artificial filter pack), or
- Pre-packed between two manufactured well screens (called "pre-packed well screens") and developed.

This "packed" zone separates the well screen from the natural aquifer material to prevent finer materials from entering the well and increases the effective well diameter. The filter pack should extend several metres above the top of the screen to allow for settling during development.

Fishing
: Retrieving a lost object in a well.

Flowing (Active) Sand
: A saturated sand deposit that flows upward into a well. Flowing sand problems typically occur during well construction when the hole reaches the saturated sand deposit. Flowing sand is also known in the industry as "running sand" or "active sand".

Flowing Artesian Well
: A flowing well (see flowing well and static water level in Table 2-1 in Chapter 2: Definitions & Clarifications)

Flush-Mounted Well Pit(Vault)
: An enclosure for the top of a test hole or dewatering well that is flush with the ground surface. This enclosure is a type of well pit.

Formation
: A mappable body of bedrock or overburden material that is recognizable by its physical and mineralogical characteristics and by its location within the geological time record (see subsurface formation in Chapter 2: Definitions & Clarifications, Table 2-1)

Formation Stabilizer
: Sand or gravel placed in the annular space of the well to provide temporary to long-term support for suitable sealant in the annular space of a well.

Fracture
: Voids in bedrock or overburden (e.g. till or clay) as a result of structural stresses (e.g. folding or faulting).

Gel
: A state of a colloidal suspension in which shearing stresses below a certain finite value fail to produce permanent deformation. Gels commonly occur when the dispersed colloidal particles have a great affinity for the base fluid.(GWW)

Gel Strength
: The thixotropic (i.e. fluid when mixed that gels when left to stand) property of a drilling fluid that allows it to form a gel when it stops moving.(GWW/NGWA)

Geological Log
: See Log of Overburden and Bedrock materials in Table 2-3 in Chapter 2: Definitions & Clarifications.

Graded
: An engineering term pertaining to a soil or an unconsolidated sediment consisting of particles of several or many sizes. The material can be described as well graded or poorly graded.(GWW)

Gradient
: The rate of change in value of a physical or chemical parameter per unit change in position.(GWW/NGWA)

Grain Size
: General dimensions of sediment or rock particles.(GWW/NGWA)

Gravel Pack
: See filter pack

Groundwater
: Underground water that fills pores in soils or openings in bedrock to the point of saturation.(Gowen)

Groundwater Divide
: The rather vague division between groundwater basins.(Gowen)

Groundwater Flow
: The movement of groundwater through openings in overburden and bedrock.(Gowen)

Groundwater Mining
: The permanent depletion of groundwater resources.(Gowen)

Groundwater Recharge (Catchment) Area
: An area that contributes to the natural replenishment (recharge) of the groundwater. It may include localized discharge areas. It typically includes the infiltration of precipitation and its movement through pores and fractures to the groundwater.(Gowen)

Groundwater Table
: The surface between the zone of saturation and the zone of aeration and includes the surface of an unconfined aquifer.(Gowen)

Grout
: A fluid mixture of cement or bentonite with water of a consistency that can be forced through a pipe and placed as required.(GWW) It can be a suitable sealant or an abandonment barrier material if it meets the requirements of the *Wells Regulation*.

Grouting
: The operation by which a sealant is placed in a well's annular space or abandonment barrier is placed in an abandoned well including its annular space.

Hardness
: A property of water causing the formation of an insoluble residue when the water is used with soap. It is primarily caused by calcium and magnesium ions.(GWW)

Head(Hydraulic Head)
: The energy contained in a mass of water that is produced by elevation, pressure, or velocity.(GWW)

Head Loss
: That part of head energy which is lost because of friction as water flows.(GWW)

Heterogeneous
: Nonuniform in structure of composition throughout.(GWW)

Hole Stabilizer
: A steel casing, a concrete tile, other temporary structure or drilling fluid (mud) which prevents the formation from collapsing into the well during well construction.

Homogeneous
: Uniform in structure or composition throughout.(GWW)

Hydration
: The act by which a substance takes up water by absorption and/or adsorption.

Hydraulic Conductivity
: A measure of the ability of a fluid to flow through a porous medium determined by the size and shape of the pore spaces or fractures in the formation and their degree of interconnection and also by the viscosity of the fluid.

Hydraulic Gradient
: The slope of the groundwater level or water table. It is the driving force of fluid flow in a porous medium. The hydraulic gradient indicates which direction groundwater will flow and how rapidly.

Hydrofracing
: See Hydrofracturing

Hydrofracturing (Hydraulic Fracturing)
: The process whereby water is pumped under high pressure into a bedrock well to fracture and clean out the reservoir rock surrounding the well bore. It is used in an attempt to increase the yield of low producing water wells in bedrock where joint systems or fractures are poorly developed. It is also used in well development immediately after new well construction.

Hydrogeologist
: A person who specializes in hydrogeology and is a Professional Engineer or a Professional Geoscientist.

Hydrogeology
: A of geology dealing with the study of groundwater, with particular emphasis on the chemistry and movement of water.

Hydrologic Cycle
: The continued circulation of water between the ocean, atmosphere and land.

Impermeable
: Watertight, or not capable of being penetrated, as in the case of rock or soil not allowing the passage of water.

Impermeable Layer
: Layer of solid material, such as rock or clay, which does not allow water to easily pass through

Inertial Lift Pump
: A manual well pump with a one-way foot valve typically attached to polyethylene tubing. This pump operates by moving the top of the tube up and down. This type of pump is commonly used in monitoring wells to sample the well water.

Infiltration
: Flow of water from the land surface into the subsurface. The movement of water (typically from precipitation), or other liquid down through pores or fractures in soil and bedrock.

In Situ
: In its original place; unmoved; unexcavated; remaining in the subsurface.

Interference(Quality)
: The condition occurring when the cone (area) of influence of a water well comes into contact with or overlaps that of a neighbouring well that are both pumping from the same aquifer or are located near each other. In some cases the pumping causes a well to go dry.

Jetting
: Propulsion of water under high pressure into sandy aquifers to create a hole for the installation of a driven-point well.

Kelly
: Hollow steel bar that is the main section of drill string to which the power is directly transmitted from the rotary table of a drilling rig to rotate the drill pipe and bit or to rotate the bucket on a boring rig.

K-Packer
: A threaded metal device covered in neoprene, or other type of rubber, that is used to connect the top of the well screen to near the bottom of the casing. The device can be used to seal the annular space between two casings or between a casing and the open borehole. A k-packer can be considered a suitable sealant in some cases.

Larminar Flow
: Water flow in which the stream lines remain distinct and in which the flow direction at every point remains unchanged with time. It is characteristic of the movement of groundwater through a well screen.

Leakage
The flow of water from one hydrogeologic unit to another. It may be natural or through a structure like a well or other preferential pathway.

Lower Explosive Limit (LEL)
The concentration of a gas in air above which the concentration of vapours is sufficient to support an explosion.

Lost Circulation
The result of drilling fluid escaping from the borehole into the formation by way of pores or fractures in the formation.

Naturally Developed Well
A well in which the well screen is placed in direct contact with the aquifer materials and developed such that the fine native material is drawn through the well screen and the coarse material is graded against the outside of the screen forming a natural filter pack.

Nominal
Used to describe standard sizes for pipe from 3.2 mm to 305 mm (1/8 inch to 12 inches). The nominal size is specified on the basis of the inside diameter. Depending on the wall thickness, the inside diameter may be less than or greater than the number indicated.

Oxidation - Reduction (Redox)
A chemical reaction consisting of two half reactions. They are an oxidation reaction in which a substance loses (or donates) electrons and a reduction reaction in which a substance gains (or accepts) electrons.

Partial Penetraion
A condition where the intake portion of the well is less than the full thickness of the aquifer.

Packer(s)
A tightly fitting device placed in a well to isolate or seal a portion of a well. Packers can be installed in pairs to seal the section of a well between two packers. In some cases only one packer will be placed to isolate the section of the well between the packer and the bottom of the well.

Pathogen
A disease causing microbial agent. Generally, any bacteria, viruses, protozoans or fungi that can cause disease in humans, plants or animals.

Peak Water Demand
The highest rate of water use each day. Well capacities or storage facilities should be designed to meet this demand.

Perched Aquifer
It is considered a special case of an unconfined aquifer. It can occur wherever an impervious (or semi-impervious) layer of limited aerial extent is located between the regional water table of an unconfined aquifer and the ground surface.

Perched Groundwater
Unconfined groundwater separated from an underlying main body of groundwater by a confining layer.

Percolation
See Infiltration

Perfirations
Slits cut into the well casing to form a well screen allowing groundwater to enter the well. They may be located at more than one level, to coincide with water-bearing strata in the earth.

Permeability
The ability of an aquifer or water-bearing formation to allow water to pass through it; the capacity of an aquifer to permit the movement of water. It is also a measure of how easily water flows through a material. Often used as a synonym for hydraulic conductivity.

pH
A measure of the relative acidity or alkalinity of water. A pH of 7 is neutral. Values less than 7 are acidic and greater than 7 are basic (alkaline).

Piezometric Surface
See Potentiometric Surface.

Pitless Adapter
A metallic (usually brass) fitting that is attached to the casing below the frost line to connect the in-well drop pipe (waterline) to the buried horizontal pipe (waterline) leading to point of use. If properly installed, the connection will be watertight to the casing. It allows the pipe to pass horizontally through the casing so that no pipe is exposed above ground where it could freeze. The device is designed to replace the need for well pits and pump houses.

Polymer
A substance formed by the union of two or more molecules of the same kind linked end to end into another compound having the same elements in the same proportion but a higher molecular weight and different physical properties.

Pore Space
Small openings in a formation filled with air or water.

Porosity
The ratio of voids or porous openings in overburden or bedrock to the total volume of the overburden and bedrock.

Potentiometric Surface
A surface that represents the level to which groundwater in a confined aquifer would rise in a well when encountering the aquifer. If the hydraulic head varies significantly with depth in the aquifer, then there may be more than one potentiometric surface. The

water table can be considered to be the potentiometric surface for an unconfined aquifer.

Pressure Grouting

A process by which grout is confined within the hole or casing by the use of retaining plugs in packers, and by which sufficient pressure is applied to drive the grout slurry into the annular space or zone to be grouted.

Pressure Head

The height of a column of static fluid (water) which is necessary to develop a specific pressure.(Gowen)

Preofessional Engineer

An Engineer in good standing licensed pursuant to the *Professional Engineers Act*, R.S.O. 1990, c. P.28.

Professional Geoscientist

A Geoscientist in good standing registered pursuant to the *Professional Geoscientists Act, 2000*, S.O. 2000, c. 13.

Pumping Test

An aquifer test that is conducted to determine aquifer or well characteristics.

Pumping Water Level

An aquifer test that is conducted to determine aquifer or well characteristics.

Radius Of Influence

The distance from the centre of a well to the outermost point of the cone of depression where the drawdown approaches zero.

Raw Water

Surface or groundwater that is available as a source of drinking water but has not received any treatment.

Recharge

The process by which an aquifer is replenished with water. This can also mean the quantity of water infiltrating from the surface and percolating to aquifers

Recharge Area

An area in an aquifer where there are downward components of hydraulic head. In this area, infiltration travels downward into the deeper sections of the aquifer.

Reciprocating Pump

A pump where the motor sitting above the well moves a piston up and down inside a cylinder in the well casing. On the upstroke, water is pulled into the pipe. A check valve at the foot of the pipe prevents water from flowing out of the pipe on the downstroke. It works the same way as a hand pump.

Recovery Rate

Rate at which the groundwater level rises in the well after pumping stops.

Residual Drawdown

The difference between the original static water level and the depth to the water level in a well at a given instant during the recovery period.

Riser

The pipe extending from the slots in the well screen to the well casing in a telescopic well screen. It is also sometimes referred to as the well casing or the drop pipe.

Safety Rope

Nylon rope used to secure the pump in case of pipe breakage.

Sampling And Analysis Plan

As part of the *Records of Site Condition Regulation*, this plan is created by a qualified person when planning for the site investigation component of a phase 2 environmental site assessment and includes a quality assurance and quality control program, data quality objectives, standard operating procedures and a description of any physical impediments that interfere with or limit the ability to conduct sampling and analysis.

Saturated

Pores in a medium filled with water.

Saturated Zone

The zone below and including the water table in which all pore spaces or fissures are totally filled with water. Also referred to as the phreatic zone.

Shear

see Shear Strength and Shear Stress

Shear Strength

The maximum resistance of a soil or rock to shearing stresses. It can also refer to the measure of shear or gel properties of a drilling fluid or grout.

Shear Stress

The component of stress which acts tangential to a plane through any given point in a body.

Shore Well

A hole in the ground located at or near the shore or bank of any surface water that is designed to take water only from surface water sources such as a lake or river. For further clarification, a hole is not considered a well as long as the hole does not encounter groundwater and is not subject to the requirements of the *Wells Regulation* or the licensing requirements in the *Ontario Water Resources Act*. Some holes close to surface water features which may have been designed to take surface water may also take groundwater. In this case the hole is considered a well under the *Ontario Water Resources Act* and the *Wells Regulation* requires the well owner to prevent the entry of surface water from entering the well.

Sieve Analysis

Determination of the particle-size distribution of a soil, sediment, or rock by measuring the percentage of the particles that will pass through standard sieves of various sizes.

Slug Test
: A test carried out to determine in situ hydraulic conductivity by instantaneously adding a known water quantity (or solid object of known displacement) to a well and measuring the resulting recovery of the water level. Also known as a falling head test.

Specific Capacity
: The yield of water per unit (metre or foot) of drawdown while pumping the well. Typically, specific capacity will decrease as pumping time or the pumping rate increase.

Specific Gravity
: The weight of a particular volume of any substance compared to the weight of an equal volume of water at a reference temperature.

Specific Storage
: The quantity of water released from or taken into storage per unit volume of a porous medium per unit change in head.

Specific Yield
: The ratio of the volume of yield of water by gravity drainage from bedrock or overburden (after being saturated) to the volume of the bedrock or overburden.

Spring
: A natural groundwater discharge on the land where the water table is higher than the ground surface. Pressure forces the water out of the land at a weak point, which creates the spring. For further clarification, if works are constructed around a spring or if equipment is installed for the collection or transmission of water, and the water is likely to be used for human consumption, then the spring is considered a well.

Standard Operating Procedures
: as part of the *Records of Site Condition Regulation*, these procedures are developed by a qualified person when any of the following field investigation methods are used in the field investigation component of a phase 2 environmental site assessment:

- borehole drilling;
- excavating;
- soil sampling;
- field screening measurements, including calibration pridcedures;
- monitoring well installation;
- monitoring well development;
- field measurement of water quality indicators, including calibration precedures;
- sediment sampling, and
- groundwater sampling.

Strata
: Layers of deposited rock, overburden, etc. which are distinguishable from each other.

Submersible Pump
: Submersible pumps are long, narrow pumps that fit into the well and sit below the water level. They are connected to the surface by a plastic or steel pipe and a waterproof electrical cable. The water flow in the well provides cooling for the motor.

Surface Water
: Water that is on the earth's surface, such as streams, rivers, lakes or reservoirs.

Surfactant
: A substance capable of reducing the surface tension of a liquid in which it is dissolved. Used in air-based drilling fluids to produce foam, and during well development to disaggregate clays.

Surge Block
: See Surging

Surging
: Development technique used with cable tool and rotary drills utilizing a surge block. A surge block consists of two or more rubber disks sandwiched between steel plates. Up and down movement of the surge block in the well forces water to flow into and out of formation

Sustained Yield
: The rate at which groundwater can be withdrawn from an aquifer without long term depletion of the supply.

Stabilzer
: See Collar

Tensile Strength
: The resistance of a material to a force tending to tear it apart.

Total Dissolved Solids (TDS)
: Term that expresses the quantity (mass) of dissolved material in a sample of water typically expressed in milligrams per litre.

Transmissivity
: The rate at which groundwater can flow through an aquifer section of unit width under a unit hydraulic gradient. It is the average permeability of a section of the entire aquifer at a given location multiplied by the thickness of the formation.

Unconfined Aquifer (Water Table Aquifer)

An aquifer confined only by the lower impermeable layer. Water usually saturates only part of the geologic unit and there is no upper confining layer. In an unconfined aquifer the water table is exposed to the atmosphere through openings in the overlying materials. In an unconfined aquifer, the cone of depression is a cone-shaped depression in the water table where the formation has actually been dewatered.

Unconsolidated Formations
: Formations of materials that are loose (not lithified), such as sand, gravel, silt and clay.

Underreamer
: A wing on a drill bit that can allow a drill bit to swing out into the formation below the casing during drilling and retract into the casing when drilling is completed.(GWW)

Unsaturated
: Pores containing air or a mixture of air and water.

Unsaturated Zone
: The zone above the water table in which soil pores or fissures are less than totally saturated. It is also called the vadose zone or the zone of aeration.

Upgradient
: An upward hydrologic slope. Wells that are upgradient of a source of contamination are less prone to receive the contaminants at elevated concentrations.

Viscosity
: The property of a substance to offer internal resistance to flow. Specifically, the ratio of the shear stress to the rate of shear strain.

Water Table
: The top of the zone of saturation where the surface is not formed by a confining unit.

Water Table Aquifer
: See Unconfined Aquifer

Wellhead
: The visible part of the well above the ground surface or above a floor.

17. Ontario Legislation

Links to relevant legislation are provided below.

Ontario Water Resources Act, R.S.O. 1990, c. O. 40

R.R.O. 1990, *Regulation 903 (Wells)* as amended made under the *Ontario Water Resources Act*, R.S.O. 1990, c. O. 40

18. Resources

Contact Information

Spills Action Centre:

Wells Help Desk:

- Tel:
- Fax:

Email: Wellshelpdesk@ontario.ca

Ministry Of The Enviroment And Climate Change - Regional, District And Area Offices

Figure 1: Map Of Ministry Regions

For a list of addresses and phone numbers of the Regional, District and Area offices of the Ministry, visit the Ministry of the Environment and Climate Change regional and district offices webpage.

Public Health Units

For a list of addresses and phone numbers of Regional, District and Area Public Health Units, visit the Ministry of Health and Long-Term Care Public Health Unit Locations webpage.

Conservation Authorities

There are thirty six conservation authorities located in Ontario. For a list of the addresses and phone numbers, visit the Ontario Conservation Authority contact list webpage.

Internet Resources

Provincial Resources

Association Of Professional Geoscientists Of Ontario

Environmental Commissioner Of Ontario's Resources Library

Ministry Of The Environment And Climate Change Water Wells Website: Government of Ontario

Ministry Of The Environment And Climate Change Water Well Ontario Website (This Website Has A Database Of Licenced Well Contractors): Government of Ontario

Ontario Association Of Certified Engineering Technicians And Technologists

Ontario Ministry Of Agriculture, Food And Rural Affairs Publications - Information on care and maintenance of private wells; including, what to do in times of water shortage, maintaining water quality, protecting drinking water and proper construction and abandonment of wells.

Ontario Ground Water Association (OGWA): "Created in 1952 as a not-for-profit organization to facilitate the various sectors of the groundwater industry coming together for the delivery of safe and clean water supplies throughout the Province."

Professional Engineers Ontario

Service Ontario E-Laws

Canadian Resources

Alberta Department Of Agriculture And Rural Development: Water Wells that Last Generations Online Manuals for the construction, maintenance and abandonment of water wells.

Canadian Groundwater Association - "national voice of the groundwater industry in Canada"; includes numerous fact sheets on groundwater and sanitizing a water well, etc."

Canadian Waste Water Agency(CWWA) - Provides wastewater treatment resources

Environment Canada - Green Lane: Provides information about environmental preservation including the conservation and protection of Canada's water resource.

Fleming College - For information about training courses for well technicians in Ontario

Ontario Clean Water Agency (OCWA) - provides wastewater treatment resources:

Canadian Water Resources Association - "Promoting Effective Water Management":

Ontario Water Works Association (OWWA) - "A voluntary membership organization of drinking water professionals dedicated to protecting public health through the delivery of safe, sufficient and sustainable drinking water in Ontario."

International Resources

Most of the following sites are U.S. based water information sites and include general and global information on water resources and issues.

American Groundwater Trust - Educational organization regarding the hydrologic, economic and environmental significance of groundwater; includes a 12-part groundwater education series

Oregon State University - Groundwater Stewardship – provides basics of understanding groundwater and its protection

National Sanitation Foundation

U.S. National Groundwater Association

UK's Centre Of Ecology And Hydrology

Water Magazine.com - Water policy ideas and information from around the world

U.S. Environmental Protection Agency - Number of articles on groundwater, aquifers, wells, etc.; also general water articles such as water cycle; link to groundwater primer on basics, quality, what you can do, protection programs, glossary and references

American Water Works Association

Michigan Department Of Environmental Quality

NSF Certified Product And Service Listings

Conversion Tables

To Convert: On the left hand column of the table is the SI (Systeme International d'Unites). To convert from Metric units to Imperial units, simply multiply by the conversion factor in the upper portion of each cell. To convert from the Imperial units to Metric units, simply multiply by the conversion factor in the lower portion of each cell. The arrows next to each conversion factor show the direction of the conversion.

Table 1: Conversion Table for Area and Volume Measurements

m^2	× 10.7639 → ← × 0.0929	square feet
m^2	× 1.196 → ← × 0.8361	square yards
m^2	$\times 2.471 \times 10^{-4}$ → ← × 4046.9	acres
ha	× 2.471 → ← × 0.40469	acres
cm^3	× 0.061024 → ← × 16.387	cubic inches
m^3	× 35.315 → ← × 0.02832	cubic feet
m^3	× 219.9 → ← $\times 4.546 \times 10^{-3}$	Imperial Gallons
L	× 0.2199 → ← × 4.546	Imperial Gallons
mL	× 0.000219 → ← $\times .4346 \times 10^{-5}$	Imperial gallons
m^3	$\times .2199 \times 10^{-3}$ → ← $\times 4.546 \times 10^{3}$	Million Imp. gallons

Table 2: Conversion Table for Length Measurements

mm	× 0.03937 → ← × 25.4	Inches
mm	$\times 3.28 \times 10^{-3}$ → ← × 304.8	feet
cm	× 0.3937 → ← × 2.54	inches
cm	× 0.0328 →	feet

	← × 30.48	
m	× 39.37 → ← × 0.0254	inches
m	× 3.281 → ← × 0.3048	feet
km	× 3280.84 → ← × 0.3048 × 10^{-3}	feet
km	× 1093.61→ ← × 9.144 × 10^{-4}	yards
km	× 0.6214 → ← × 1.609	miles

Table 3: Conversion Table for Weight and Mass Measurements

g	× 2.205 × 10^{-3} → ← × 0.064799	pounds
g	× 15.4323 → ← × 0.064799	grains
g	× 0.03527→ ← × 28.3495	ounces
mg	× 2.205 × 10^{-6} → ← × 453592.3	pounds
mg	× 0.01543 → ← × 64.799	grains
kg	× 2.2046 → ← × 0.4536	pounds

Table 4: Conversaion Table for Pressure Measurements

Pa	× 0.145 × 10^{-3} → ← × 6.895 × 10^{3}	pounds per square inch
kPa	× 0.145 → ← × 6.895	pounds per square inch
kPa	× 4.0145 → ← × 0.249	inches of water column
kPa	× 0.295 → ← × 3.386	inches of mercury col.
psi	× 2.31 → ← × 0.433	Feet of water depth
kPa	× 0.102 → ← × 9.8	Metres of water depth

Table 5: Conversion Table For Work/Energy & Power Measurements

J	× 0.7376 → ← × 1.356	foot pounds
kJ	× 0.9478 → ← × 1.055	BTU
kW	× 1.341 → ← × 0.7457	hp (electric)

Table 6: Table for Temperature

°C	(1.8 × °C) + 32 →	°F

	← (°F − 32) × 0.5556	

pH

A pH scale is used to measure the acidity of a substance. A pH lower than 7 indicates an acidic substance (maximum acidity = 0), and pH greater than 7 indicates a less acidic – or more alkaline – substance (maximum alkalinity = 14). A pH of 7 is neutral. Pure water has a pH of 7 [1] .

Figure 2: pH Scale

Mathematical Symbols Found In This Manual

Symbol	Name	Description
>	Greater-than	Used to express a larger value than a given value. For example: in the expression (x > y) ; x has a greater value than y.
≥	Greater than or equal to	Used to express a value that can be either a larger value or the same value as a given value. For example: in the expression (x ≥ y) ; x has a either a greater value than y or it has the same value as y.
<	Less-than	Used to express a lesser value than given value.
≤	Less-than or equal to	Used to express a value that can be either a lesser value or the same value as a given value.
π	Pi	Approximately equal to 3.14; pi is a mathematical constant representing the ratio of a circle's circumference to its diameter.

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- [**] ^ Class 3 licence only authorizes activities specified in the licence and the licensee can only abandon a well if it is specified on the class 3 licence (e.g., jetting/driving).

- [***] ^ Unless exempt, the person abandoning the well, often the well owner, must retain a licensed well contractor and must ensure that the contract between them requires that a well technician licensed to construct the type of well that is being abandoned to be used to abandon the well. See “Plainly Stated” and “Responsibilities of the Person Abandoning the Well for Abandonment Operations” section in this chapter. See Chapter 13: Well Records, Documentation Reporting & Tagging, “Well Record Information” section, and Chapter 15: Abandonment – How to Plug and Seal Wells for further information on the person abandoning the well.
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