Directive 051

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Replaces previous edition issued March 1, 1994

Injection and Disposal Wells – Well Classifications, Completions, Logging, and Testing Requirements

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Contents

1 Introduction

1.1 Purpose of This Directive

The purpose of this directive is to ensure wellbore integrity during injection or disposal operations. In all cases, the location and purpose of the well must be approved as part of a specific scheme approval as required by the following regulations as applicable:

- *Oil and Gas Conservation Act*
- *Oil and Gas Conservation Rules (OGCR)*
- *Oil Sands Conservation Act*
- *Oil Sands Conservation Rules*
- *Geothermal Resource Development Act*
- *Geothermal Resource Development Rules*

This directive

- provides the criteria to determine the well class for injection or disposal based on the fluid type;
- provides the requirements for completion, logging, testing, and monitoring for each well class; and
- identifies the information required for submission in support of an application for approval to inject or dispose of fluids subsurface and operating and monitoring procedures.

Appendix 1 is a quick reference guide summarizing the requirements for each well class.

In this directive, defined terms are set in **boldface** at first use, and the definitions are provided in appendix 2.

1.2 AER Requirements

Following Alberta Energy Regulator (AER) requirements is mandatory for the responsible duty holder as specified in legislation (e.g., licensee, operator, company, applicant, approval holder, or permit holder). The term “must” indicates a requirement, while terms such as “should,” “recommends,” and “expects” indicate a recommended practice.

Each AER requirement that is unique to this directive is numbered.

The requirements in this directive apply to new injection or disposal wells and any other type of existing wells for conversion to an injection or disposal well. In both cases, requirements refer to the applicant.

Information on compliance and enforcement can be found on the AER website.

Direct any questions about this directive to WellOperations@aer.ca.

1.3 What's New in This Edition

Directive 051 has been rebranded, reorganized, and placed in the AER's current format for directives. Unique requirements have been numbered.

The following changes have also been made to this directive:

- removed duplicate requirements found in other directives as part of the red tape reduction initiative
- added requirements for geothermal wells, including adding relevant definitions, and references to applicable legislation
- added requirements relating to carbon capture, utilization, and storage
- clarified the criteria for class Ia and class Ib disposal wells
- added a reference to *Directive 087: Well Integrity Management* for ongoing testing requirements
- removed the requirements for default maximum wellhead pressure and step-rate injectivity requirements, which are found in *Directive 065: Resources Applications for Oil and Gas Reservoirs*
- revised the **packer isolation test** definition and the criteria for a successful test
- revised the information requirements for the Well Summary for Injection or Disposal form (removed "well name," "fracture gradient," and "cathodic protection installed")
- removed the minimum allowable wellhead injection pressure table (refer to *Directive 065*)
- revised the appendices

1.4 Compliance with Regional Plans

The AER is legally obligated to act in compliance with any approved regional plans under the *Alberta Land Stewardship Act*.

1) To ensure this compliance, the AER requires any applicant seeking approval for injection and disposal of fluids located within the boundary of an approved regional plan must meet the requirements set out in *Directive 056: Energy Development Applications and Schedules*.

2 Deepwell Disposal

2.1 Principles

Deepwell disposal of oilfield and industrial wastewater in Alberta is a safe and viable disposal option where wells are properly constructed, operated, and monitored. The AER expects the waste generator to consider and be guided by the following principles when deciding on deepwell disposal:

- **Waste minimization** should be implemented before using the deepwell disposal option.
- Resource conservation, including surface water and the waste streams themselves, should be pursued whenever possible.
- Disposal wells are classified and designed based on the fluid to be disposed of, which will determine the monitoring and surveillance requirements (i.e., the more sensitive the fluids, the more monitoring and surveillance are required).
- Waste fluids should not be diluted to avoid waste fluid classification.
- Operators of surface facilities that generate or process waste material disposed of through class Ia or class Ib wells are expected to design and operate those facilities using sound waste management practices and principles of waste minimization.

Regulatory activities for deepwell disposal will focus on:

- wellbore integrity to ensure initial and ongoing containment of the disposal fluid in the interests of hydrocarbon conservation and groundwater protection;
- formation suitability to ensure initial and ongoing confinement of the disposal fluid in the interests of hydrocarbon conservation and groundwater protection;
- suitability of the waste stream for deepwell disposal having regard for the nature of the fluid, the integrity of the well, and alternative waste management options;
- reporting and manifesting of disposed waste; and
- where appropriate, ensuring the principles have been followed.

Matters of fluid-fluid, fluid-equipment, and fluid-formation compatibility will be left primarily to the disposal well operator, with regulators relying on operating and monitoring requirements to provide for early detection and mitigation of potential problems. The waste generator has the responsibility to ensure waste minimization and resource conservation principles are followed.

In all cases, the waste generator is responsible for ensuring each waste stream has been properly identified, characterized, handled, treated, and disposed of in an acceptable manner.

2.2 Fluids Prohibited from Disposal

Except under exceptional circumstances, the following waste streams are prohibited from disposal by subsurface injection:

- municipal or industrial sewage[1]
- surface water runoff[1] that meets surface discharge criteria or can meet surface discharge criteria without cost-prohibitive treatment
- lube oils and spent solvents, which are considered recyclable
- hydrocarbon-based drilling fluids, which are considered recyclable
- waste where appropriate treatment technology exists (economically and technically)

3 Well Classifications

2) Operators must have a well licence appropriate to the type of fluid injected or disposed of before injecting or disposing of fluids subsurface.

Injection and disposal wells are classified based on the characteristics and types of fluids for injection or disposal. The well classification will determine design, operation, monitoring, and surveillance requirements. Figure 1 is a decision tree to assist in identifying the well class based on the fluid type. Except for acid gas disposal for class III, well classes II, III, and IV are used for injection of fluids not classified as waste. Well classes Ia and Ib are used for disposal of waste fluids.

3.1 Class IV Well

Class IV wells are used to inject potable water (with no expectation of its conversion to produced water) or steam made from either potable water or recycled water into a reservoir.

3.2 Class III Well

Class III wells are used to inject hydrocarbons, inert gases, or other gases for enhanced recovery or storage in a reservoir, which may include the following:

- solvent or other hydrocarbon products used for enhanced recovery operations
- sweet gas used for gas storage operations
- carbon dioxide (CO_2), nitrogen (N_2), oxygen (O_2), air, or other gases used for storage or enhanced recovery
- CO_2 used for **CO_2 EOR storage scheme** or **CO_2 sequestration scheme**

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[1] The preferred waste management option is treatment and return to the surface or watershed. Treatment technologies are standard and well established. This approach adheres to the principle of water conservation.

- sour or acid gases for disposal, storage, or cycling operations

3.3 Class II Well

Class II wells are used to inject or dispose of produced water (brine) or **brine-equivalent** fluids and include the following:

- produced water from the recovery of oil, bitumen, gas, coalbed methane, and geothermal resources through an **open-loop configuration** (geothermal well)
- brine from a salt cavern or solution mining operation
- water-based pigging fluids from cleaning of collection and injection lines
- brine reject or backwash from water softeners associated with enhanced recovery
- water containing polymers or other chemicals for enhanced recovery
- waste fluids from circulation during well cementing
- calcium chloride ($CaC1_2$) water
- potassium chloride (KCl) water is a brine equivalent

3.4 Waste Fluid Disposal Wells

The following applies to subsurface waste disposal classification only and does not override the *Transportation of Dangerous Goods Regulations* sampling and analysis criteria for waste transportation.

Where subsurface disposal is not an option, see *Directive 058: Oilfield Waste Management Requirements for the Upstream Petroleum Industry* for alternative disposal options.

Wells accepting waste beyond common oilfield or similar waste should be considered as class Ia and subject to a program of ongoing monitoring and review.

Waste fluids (i.e., class Ib and class Ia) are suitable for deep well disposal in Alberta if a representative sample of the waste does not exceed the following criteria for class Ia fluids:

- a pH between 4.5 and 12.5[2]
- a nonhalogenated organic fraction of less than 10% by mass (100 000 milligrams per kilogram [mg/kg])[3] unless
  - it is untreatable sand or an oil-water emulsion[4], or

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2 Recognizes potential wellbore integrity problems due to corrosiveness.

3 Considered to be of sufficient heat value to make incineration or recycling economically feasible.

4 Return to the subsurface (i.e., origin) is considered an appropriate waste management option.

  - it is antifreeze or a dehydration fluid that contains greater than 60% water by mass[5]
- one or more halogenated organic compounds in a total combined concentration of less than 1000 mg/kg[6]
- a polychlorinated biphenyl (PCB) concentration of less than 2 mg/kg[7]
- a heavy metal concentration above the levels set out in table 1[8]

3.4.1 Class Ib Wells

The following list of aqueous fluids was compiled based on historical data and experience with waste streams resulting from standard industry practices and is considered appropriate for disposal in class Ib wells without further sampling and analysis:

- acidic or alkaline solutions (neutralized[9]) with heavy metal concentrations at or below the levels set out in table 1
- amine filter backwash (e.g., monoethanolamine [MEA], diethanolamine [DEA], methyl diethanolamine [MDEA])
- aqueous liquid fractions (neutralized[9]) of spent sweetening agents (e.g., Cansweet 200, 300, 300SX, and 500, SulphaCheck, and Sulfa-Scrub)
- boiler blowdown water
- corrosion inhibitor solutions with heavy metal concentrations at or below the levels set out in table 1
- gas scrubber or absorption tower bottom liquids (neutralized[9]) with heavy metal concentrations at or below the levels set out in table 1
- glycol solutions as obtained from dehydration operations
- inorganic salts used in heat exchange medium (e.g., sodium, potassium nitrates, nitrites) properly solubilized using an existing aqueous waste stream
- liquid fraction of drilling muds, including KCl muds, but not hydrocarbon-based drilling fluids (prohibited in accordance with section 2.2)
- methanol or hydrotest solutions

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[5] Recycling is considered economically feasible up to a water content of 60% by mass.

[6] Recognizes health and environmental risks based on the *Environmental Protection and Enhancement Act* land disposal restrictions for liquid or solid hazardous waste.

[7] Limitation based on federal and provincial environmental regulations.

[8] Limitation based on the *Environmental Protection and Enhancement Act* land disposal restrictions of liquid hazardous waste. Restriction recognizes less stringent operational and monitoring requirements for class Ib wells.

[9] Neutralized means for class Ib fluids a pH between 6.0 and 9.0.

- oxygen scavenger solutions with heavy metal concentrations at or below the levels set out in table 1
- saline fluids from oilfield waste processing facilities, oilfield tank washing operations, oil spill containment and recovery, or similar operations
- spent workover or stimulation fluids (after neutralization[9] or processing to recover hydrocarbons or both)
- sulphur block runoff water (neutralized[9])
- washing wastewater (i.e., detergent or soap waste)
- waste fluids from drilling operations (i.e., used in or originating from the wellbore)
- contaminated surface runoff water that is untreatable and unsuitable for return to the watershed

A waste fluid that is not specifically listed above is suitable for disposal in a class Ib well if it meets the following criteria:

- a pH between 6.0 and 9.0[10]
- a flash point greater than 60.5°C[11] unless
  - it is untreatable sand or oil-water emulsion[4], or
  - is antifreeze or a dehydration fluid[5]
- a heavy metal concentration at or below the levels set out in table 1[8]
- one or more halogenated organic compounds in a total combined concentration of less than 100 mg/kg[12]

3) Where operations or circumstances will result in waste qualitatively different from the generalized waste streams listed under class Ib, the applicant must sample and test the waste to determine whether it meets the criteria for a class Ib or class Ia well.

4) The well licensee, whether waste generator or waste receiver, must verify as described in *Directive 058* that the waste is the result of standard industry practices and eligible for a class Ib well.

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[10] Limitation to avoid significant corrosion and possible wellbore integrity problems.

[11] Flash point greater than 60.5°C identifies nonflammable liquids. Flammable liquids are prohibited from class Ib disposal due to less stringent monitoring and operational restrictions.

[12] Recognizes health and environmental risks based on the *Environmental Protection and Enhancement Act* land disposal restrictions for liquid or solid hazardous waste.

3.4.2 Class Ia Wells

Class Ia wells are used to dispose of oilfield or industrial waste fluids and waste streams meeting the criteria in section 3.4.

The following is a list of examples of waste streams that are generally considered class Ia fluids:

- acidic or caustic solutions
- acidic solutions with heavy metal concentrations exceeding the levels set out in table 1
- alkaline solutions with metal concentrations exceeding the levels set out in table 1
- aqueous solutions containing nonhalogenated organic compounds in concentrations less than 10% by mass
- aqueous solutions containing less than 50 milligrams per litre (mg/L) of PCBs
- aqueous solutions containing halogenated organic compounds (excluding PCBs) in concentrations less than 0.1% by mass
- aqueous solutions with metal concentrations exceeding the levels set out in table 1
- chemical process wastewater
- herbicide wastewater
- liquid tannery wastewater
- metal-finishing solutions (acidic, alkaline, or spent pickle liquors)
- oil refinery wastewater
- pesticide wastewater
- pharmaceutical wastewater
- phenolic wastewater
- slurries of alum, gypsum, or asbestos
- slurries of metals (heavy and non-)
- solutions containing reactive anions (includes fluoride, hypochlorite, bromate)
- spent photofinishing solutions

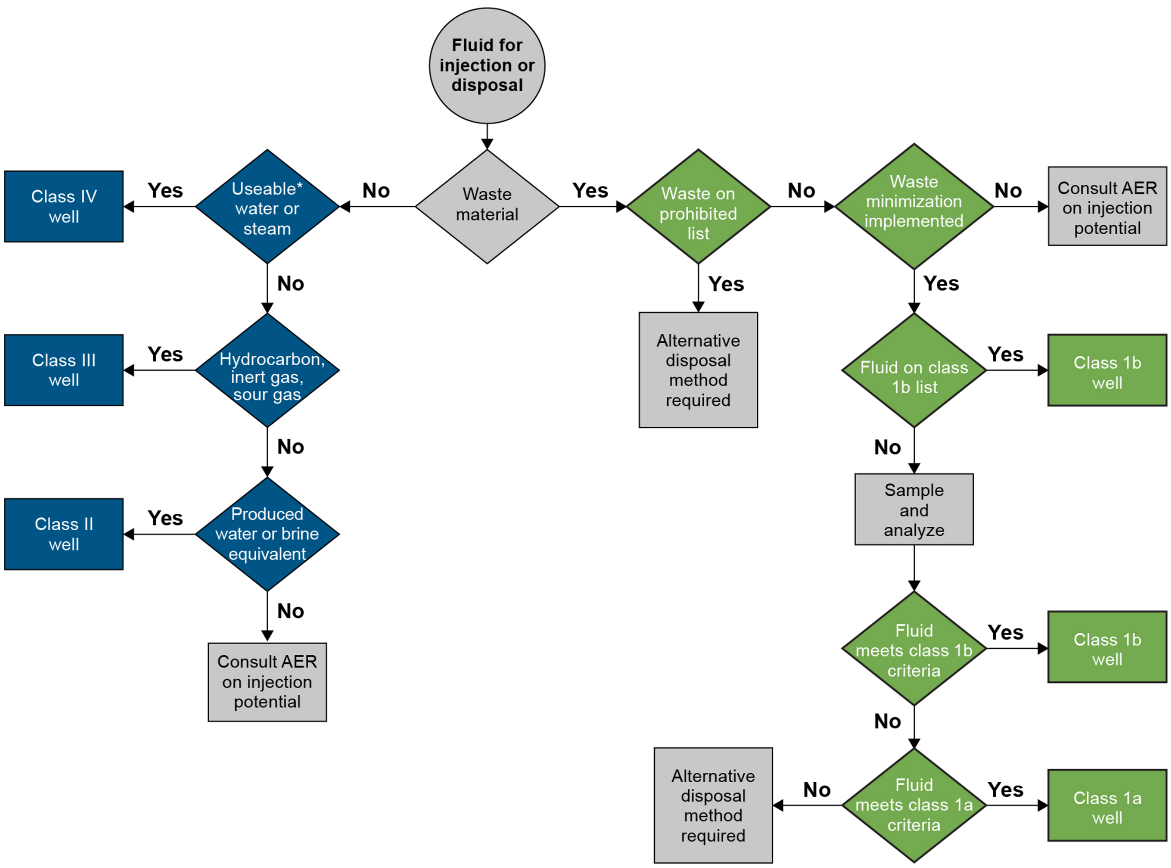
5) The licensee must sample and analyze the waste stream at a frequency sufficient to verify the waste stream continues to comply with the criteria for a class Ia well.

Where sampling and analysis indicate a waste stream meets the criteria for a class Ib well, the waste stream may be disposed of via a class Ib well.

Table 1. Metal concentration levels

Metal	Concentration level (mg/L)
Arsenic	500
Beryllium	100
Cadmium	100
Chromium	500
Lead	500
Mercury	20
Nickel	500
Selenium	200
Silver	100
Thallium	200
Uranium	100

Note: Concentration threshold levels for heavy metals based on the *Environmental Protection and Enhancement Act* land disposal prohibitions. Waste fluids above these levels, when disposed of by subsurface injection, must be through an approved class Ia disposal well.



* Useable = potable water or recycled water.

Figure 1. Well classification decision tree

3.5 Waste Reporting

Waste reporting is addressed in *Directive 058*, *Directive 047: Waste Reporting Requirements for Oilfield Waste Management Facilities*, and *Directive 007: Volumetric and Infrastructure Requirements*.

4 Cementing and Casing Requirements

Comprehensive information on cementing and casing requirements can be found in *Directive 008: Surface Casing Depth Requirements*, *Directive 009: Casing Cementing Minimum Requirements*, and *Directive 010: Minimum Casing Design Requirements*.

6) The well completion must provide hydraulic isolation of the injection or disposal zone and isolation of **nonsaline groundwater-bearing zones** to prevent cross flow of the injected fluid.

Completions that fail to satisfy these requirements may be denied or subject to tests and limitations beyond those discussed in this directive.

4.1 All Well Classes

7) All potential hydrocarbon-bearing zones and the injection or disposal zones must be isolated by cement.

8) Where thermal operations are conducted or anticipated in requirement 6, thermal cement must be used.

4.2 Well Class Ia

9) For all new class Ia wells drilled, the surface casing must be set to the **base of groundwater protection** and cemented in accordance with *Directive 009*.

Where this requirement is not met, applications for conversion of existing wells to injection or disposal service may be denied or subject to testing, monitoring, or evaluation in addition to the requirements indicated in this directive.

4.3 Well Classes Ib Through IV

10) All new class Ib through IV wells drilled for the purpose of injection or disposal must ensure nonsaline groundwater-bearing zones are isolated with the appropriate combination of surface, intermediate, or production casing cemented to surface from the base of groundwater protection.

Where this requirement is not met, applications for conversion of existing wells to injection or disposal service may be denied or subject to testing, monitoring, or evaluation in addition to the requirements indicated in this directive.

5 Initial Logging Requirements

This section identifies the initial logging requirements necessary for the approval of injection or disposal service. Ongoing logging requirements for monitoring purposes are included in section 7.4.

5.1 Cement Top Location

11) For all well classes, if the production casing is not cemented to surface or cement returns to surface are not obtained and maintained during setting, then a **cement top locating log** must be run.

5.2 Hydraulic Isolation

12) The logging requirements applicable to each well class as described in table 2 must be followed.

13) Submit all required logs listed in table 2 to the AER along with the *Directive 51* application via the Digital Data Submission system, including a detailed interpretation of the log against its specific objective, for approval before starting injection or disposal operations.

See appendix 3 for guidelines for running logs and the expectations in obtaining satisfactory logs.

Alternative logging techniques may be appropriate in certain site-specific cases.

14) Licensees wishing to use an alternative logging technique must submit a request to WellOperations@aer.ca for approval before using the alternative.

The wellhead injection pressures for class Ia, Ib, II, and III wells may be limited to the pressure at which the **hydraulic isolation logging** was conducted. These surveys should therefore be designed with consideration given to injectivity requirements.

Table 2. Logging requirements by well class

Well class	Logging requirement
Ia	A temperature survey and any one of the following: • **radioactive tracer survey** • **oxygen activation log** • **cement integrity log** A cement integrity log for wells injecting gases
Ib and II	A temperature survey and any one of the following: • radioactive tracer survey • oxygen activation log • cement integrity log
III	A temperature survey and any one of the following: • radioactive tracer survey • oxygen activation log • cement integrity log

Well class	Logging requirement
IV	Any one of the following: • temperature survey • radioactive tracer survey • oxygen activation log • cement integrity log Steam injection wells may be subject to additional logging requirements specified in their scheme approval. It is not intended to encourage radioactive tracer surveys on steam injection wells due to increased risks in handling radioactive materials in the vapour phase.

5.3 Casing Integrity

5.3.1 All Classes (Well Conversion)

15) A full-length **casing inspection log** must be run on any existing well for which conversion to injection or disposal service is proposed.

16) When assessing the casing integrity and condition using a casing inspection log, the maximum burst resistance based on the least wall thickness and minimum yield strength of the casing must be greater than 1.3 times the maximum allowable wellhead injection pressure. The following equation must therefore be satisfied.

$$P_y = 0.875\,\frac{(2Y_p\,t)}{D} \geq 1.3P_{max}$$

where

P_y	minimum internal yield pressure (kPa)
0.875	the reduction factor allowing for minimum wall thickness (API wall thickness tolerance of 12.5%)
Y_p	specified minimum yield strength (kPa)
t	nominal wall thickness or reduced wall thickness (mm)
D	nominal outside diameter (mm)
P_{max}	maximum allowable wellhead injection pressure

The maximum determined per cent penetration or metal loss will be used.

5.3.2 Class Ia (New Wells)

A baseline full-length casing inspection log is recommended for all new wells drilled for class Ia disposal. The baseline log will identify anomalies in the metallurgy and log responses that could be misinterpreted as corrosion in future logging operations.

6 Logging Waivers

Under certain circumstances, the AER will consider requests for waiver of the logging requirements described in section 5.

17) Requests for waiver of a logging requirement described in section 5 must be supported by information about the waiver criteria listed in table 3, where appropriate, and a discussion of how they relate to casing integrity or hydraulic isolation.

Table 3. Waiver criteria by log type

Log type	Waiver criteria
Casing inspection	A casing waiver will only be considered for a well that is less than five years old.
Hydraulic isolation	For a well that accepts fluid on vacuum, discuss wellbore fluid levels under injection or disposal and the proximity of the fluid level to the nearest other porous and permeable zone. Waivers will not normally be granted for class Ia and Ib wells.
Cement top locating	• open-hole caliper • slurry volumes • cement logs from similar adjacent wells • cementing program and evidence of good returns during cementing • evidence of cement top in similar adjacent wells using a similar cementing program

7 Other Tests and Submission Requirements

7.1 Packer Placement

Place packers in the wellbore in accordance with section 6.120 of the *OGCR*.

7.2 Initial Pressure Test

18) For well classes I through III, an initial pressure test of the casing or tubing-casing annulus to a minimum pressure of 7000 kPa for 15 minutes must be conducted before starting injection or disposal operations.

An initial packer isolation test is considered successful when the required pressure is applied and maintained for at least 15 minutes with variations not exceeding 3% of the applied pressure.

Except for class Ia and Ib wells, consideration will be given to reduced pressures where a packer is set in tension and may become unseated at the required pressure.

7.3 Ongoing Packer Isolation Tests

Directive 087 provides testing, reporting, and repair requirements for performing ongoing packer isolation tests.

For class Ia wells, this directive specifies ongoing monitoring and annular pressure requirements, and *Directive 087* specifies ongoing testing requirements to ensure annular integrity.

7.4 Ongoing Monitoring Programs

Directive 087 describes the ongoing monitoring and testing requirements for all wells where a packer is required.

19) The monitoring program for each well class must ensure continued wellbore and formation integrity and follow the requirements in table 4.

Table 4. Monitoring requirements

Well class	Monitoring requirements
Ia	Wellbore and formation monitoring must include: • monitoring injectivity and annular pressure at least daily • hydraulic isolation logging every five years after the initial log • annual packer isolation testing as per *Directive 087* • a positive pressure of at least 500 kPa applied to the annulus to facilitate continuous monitoring. Alternatively, a **fluid level detection system** that provides a visual indication of the annular fluid level may be used.
Ib, II, III	• annual packer isolation testing as per *Directive 087*
IV	• monitor the injection rate and injection pressure for wells under steam injection at least daily Steam injection wells may be subject to additional monitoring requirements specified in their scheme approval.

7.5 Well Summary

20) Complete the Well Summary for Injection or Disposal form (available on the *Directive 051* landing page) and the well stick diagram in appendix 4 and submit them with the application for injection or disposal.

Appendix 1 Quick Reference Guide

The following table summarizes the contents of this directive and is a quick reference only. Significant detail and explanation are included in the directive.

Section	Class Ia	Class Ib	Class II	Class III	Class IV
3 Well Classifications					
Oilfield/industrial waste	X				
Produced water/specified waste		X			
Produced water/brine equivalent			X		
Hydrocarbon/inert/sour gases				X	
Steam/potable water					X
4 Cementing and Casing Requirement					
Hydraulic isolation of host zone*	X	X	X	X	X
Cement across base of groundwater	X	X	X	X	X
Surface casing at or below base of groundwater	X				
5 Initial Logging Requirements					
Cement top locator (when no returns)	X	X	X	X	X
Hydraulic isolation	X	X	X	X	X
Casing inspection (conversion)	X	X	X	X	X
7 Other Tests and Requirements					
Annulus pressure test (initial)	X	X	X	X	
Daily annular monitoring	X				
Daily injectivity monitoring	X				
Continuous injectivity monitoring					X
Hydraulic isolation logging (every 5 years)	X				
Packer isolation test as per *Directive 087*	X	X	X	X	
Well summary/completion schematic	X	X	X	X	X
Positive annular pressure	X				

* Host zone means either the injection or disposal zone.

Appendix 2 Definitions

base of groundwater protection Base of groundwater protection is an estimate of the elevation of the base of the formation in which nonsaline groundwater occurs at that location. Variations in geology and topography are typical, so the actual elevation of the base of the formation will vary from location to location within the formation. The base of groundwater protection is set at 600 metres below ground level in the mountainous region and not set for the northeast corner of the province where the Canadian Shield outcrops. For more information, see *Base of Groundwater Protection Data*.

brine-equivalent Aqueous salt solutions that, in the opinion of Alberta Environment and Protected Areas and the Alberta Energy Regulator, are equivalent to produced water. Email welloperations@aer.ca to request a determination if a solution is a brine equivalent.

casing inspection log A log or combination of logs fully interpreted on a joint-by-joint basis, which

- determines the per cent penetration of anomalies,
- distinguishes between internal and external corrosion, and
- detects holes, pits, perforations, metal loss, and metal thickness.

cement integrity log Includes first-generation (i.e., sonic) bond or compensated bond tools or second-generation (i.e., ultrasonic pulse) cement evaluation tools. Sonic bond tools run after March 1, 1994, in accordance with section 5.2 of this directive for evaluation of hydraulic isolation must be configured, as a minimum, with dual receivers at three- and five-foot spacings from a single transmitter and must provide a variable density or full-wave train display, travel time curve, amplitude or attenuation curve, and gamma-ray curve. These requirements do not apply when the log is run specifically for the purpose of cement top location.

cement top locating log Includes temperature logs if run immediately after cementing, or any cement integrity log as defined above.

CO_2 EOR storage scheme An area approved for enhanced oil (or gas) recovery and net geological storage of CO_2 as described in *Directive 065*.

CO_2 sequestration scheme Wells approved for the permanent geological storage of CO_2 as described in *Directive 065*.

corrosion rate The rate of corrosion is considered unacceptable when any anomaly recorded on a casing inspection of log exhibits:

- greater than 20% wall loss in 5 years
- greater than 40% wall loss in 10 years
- greater than 60% wall loss in 15 years

fluid level detection system	A system which provides a continuous visual indication of the annular fluid level (e.g., monitoring pot consisting of a barrel with a sight glass connected to the annulus, partially filled with liquid such that increases or decreases of the annular fluid level can be observed).
grandfathered wells	For the purpose of this directive, wells that were approved for injection or disposal operations before March 1, 1994, are grandfathered.
hydraulic isolation logging	A suite of production logs used to evaluate the absence or presence of flow of injected fluid behind the casing string.
nonsaline groundwater	Groundwater with a total dissolved solids content of 4000 mg/L or less.
open-loop configuration	This geothermal configuration consists of groups of open-loop injection wells and open-loop production wells. During geothermal operations, such a configuration will produce warm or hot formation fluids from the subsurface to the surface and inject cooler formation fluids back into the subsurface. Also referred to as "open-loop geothermal system."
oxygen activation log	A log which employs pulsed neutron techniques to activate oxygen nuclei, creating a radioactive nitrogen isotope of very short half-life.
packer isolation test	A pressure test of the tubing and casing annulus designed to evaluate the integrity of the wellhead, casing, tubing, and packer.
radioactive tracer survey	A logging survey which injects radioactive material with a downhole injector at or near the maximum allowable injection pressure. There will be at least two gamma-ray detectors. If temperatures and pressures do not allow for this type of tool, consideration may be given to radioactive material injected at surface followed by a pass with a gamma-ray detector. Radioactive tracer materials used in these surveys should be restricted to those with a half-life of eight days or less, typically one day.
waste minimization	The process of minimizing waste production by reducing, reusing, recycling, and recovering waste. Duty holders should ensure effective management strategies are used to minimize waste.

Appendix 3 Logging Guidelines

The following are general guidelines that should be considered when logging for hydraulic isolation or casing integrity and are not requirements. However, situations may exist where certain aspects of these guidelines are not applicable. In all cases, logging company representatives should be made aware of the purpose of logging to ensure the program and tool configuration are appropriate for the specific well situation.

Hydraulic Isolation Logging

For all logs requiring active injection (i.e., temperature, radioactive tracer, oxygen activation), the following general design considerations apply:

- The well should be capable of accepting a stable flow rate, and sufficient fluid must be available to conduct the entire logging program.
- Logging should be conducted with the well under normal injection conditions, preferably at or near the approved or requested maximum wellhead injection pressure.
- Wireline pressure control equipment should be installed that can maintain a casing pressure that is at least equal to the maximum wellhead injection pressure without significant pressure bleeding off while logging.

Temperature Survey

The method of temperature survey used depends on the duration of continuous injection occurring before the survey. The temperature of the injected fluid should be adjusted, if necessary, to provide for a differential of at least 5°C at the injection zone. All temperature logs must be obtained by logging down.

Shut-in logs obtained should be presented as a composite overlay on the same axis for comparative purposes. Displays should enhance the visual identification of anomalies by compressing the depth scale and expanding the temperature scale. Preferred scaling is in the order of 10 centimetres (cm) to 100 metres (m) depth and 10 cm to 5°C. In some cases, these composite overlays and scaling may not be available from the standard log format and will require photomechanical assistance.

Method 1: Wells without previous fluid injection (e.g., new wells, extended shut-in, conversions).

This method should be used where the well has had no significant previous fluid injection activity or shut-in for an extended period and wellbore temperatures are expected to be near geothermal:

- With the well shut-in, run a baseline temperature log (logging down) and a baseline gamma-ray record (logging up) from about 200 m above the top of the zone of interest to total depth (TD) or plug back total depth (PBTD).

- Inject a volume of fluid at or near the maximum operating pressure under normal injection conditions. This would normally represent the radioactive tracer or oxygen activation logging portion of the operation.
- With the well shut-in, conduct four temperature runs (logging down) at a minimum of half-hour intervals to assist in identifying storage areas.
- For horizontal injection wells, the log should be run to the top of the injection formation.

Method 2: Well with current injection.

This method is an option to be used where a well is under current fluid injection (this is typical of class Ia wells conducting the required five-year hydraulic isolation log):

- Shut in the well and allow the wellbore temperature to return to near geothermal. The necessary shut-in time can be estimated from the table below.

Duration of continuous injection	Time for temperature stabilization (hr)
1 month	12
6 months	24
1 year	48
5 years	96
10+ years	192

- Run a temperature log (logging down) from surface to TD.
- Run a second temperature log (logging down) after six hours. If the temperatures appear to have approached long-term stability, these two logs can be used. If not, an additional period must be allowed to provide for temperature stabilization and a subsequent log run.
- For horizontal injection wells, the log should be run to the top of the injection formation.

For either method, the shut-in logs obtained should be presented as a composite overlay on the same axis for comparative purposes. Displays should enhance the visual identification of anomalies by compressing the depth scale and expanding the temperature scale. Preferred scaling is in the order of 10 cm to 100 m depth and 10 cm to 5°C. In some cases, these composite overlays and scaling may not be available from the standard log format and will require photomechanical assistance.

Radioactive Tracer Surveys

Radioactive tracer surveys can be effective for detecting near-wellbore flow behind the casing. The tracer material must be compatible with the injection fluid to avoid density segregation or dropout of the tracer material. Logging tools should be centralized to avoid tracer ejection against the casing wall. Wherever practical, the wellbore should be clear of tubing and packer over the zone of interest to avoid any radioactive tracer traps and enhance interpretation.

The logging program should be specific to the wellbore and the purpose for logging. However, it is recommended that programs include the following basic components:

- With the well shut-in, a baseline gamma-ray record (logging up) from TD or PBTD to at least 200 m above the top of the zone of interest.
- With the well under a stable injection rate at or near the maximum wellhead injection pressure, run a series of stationary tracer ejections starting above and continuing through the perforated interval until the bottom detector no longer detects the ejected slug. In cases of low injection rate, log-through procedures may be used in which the tracer ejections are not stationary.
- Inject a slug of tracer above the perforations followed by four consecutive logging runs (i.e., storage passes) from TD or PBTD to 200 m above the zone of interest until the slug disappears or becomes stationary.

The results of the storage passes should be presented as a composite overlay.

Oxygen Activation Log

The following general procedures should be followed when using oxygen activation logs for evaluating hydraulic isolation:

- With the wells under injection at or near the maximum wellhead injection pressure, take measurements at a minimum of three stations above the injection interval.
- If anomalies are found, additional readings should be taken above and below the anomalies reading to attempt to confirm the anomalous reading.

Cement Integrity Log

General Design Considerations

- The well history should be researched to determine the cement type and expected placement, casing sizes and grades, and maximum fluid pressure exerted on the casing once the annular cement has cured.
- Wireline pressure control equipment should be installed that can maintain a casing pressure of at least 7000 kPa without significant pressure bleeding off while logging.
- Tool selection and log interpretation should recognize the type of cement used.
- Properly centralize the logging tool in the casing.

Well Preparation

- Let the cement cure before logging. A minimum of 48 hours is recommended.
- The casing should be clear of any internal cement sheathing before logging.
- The wellbore should be displaced to a consistent liquid, either fresh water, drilling mud, or dead crude. Mud weights should be kept below 1200 kilograms per cubic metre (kg/m^3) to avoid signal attenuation problems.

Logging Procedures

- For injection or disposal into an interval at depths shallower than 600 m, the well should be logged from TD or PBTD to 25 m inside the surface casing.

For injection or disposal into an interval at depths deeper than 600 m, the well should be logged from 100 m above the injection or disposal zone and, depending on how the bottom of the casing is finished, from 100 m below the injection or disposal zone to either TD or PBTD if it is less than 100 m below.

- The main logging pass should, where possible, be run with the maximum historical fluid pressure on the casing to avoid micro-annulus effects.
- A section of free pipe should be logged for baseline reference and transit time and amplitude calibration.

Casing Integrity

General Design Considerations

The well history should be researched to determine all casing sizes, weights, and any activities that would influence the magnetic characteristics of the wellbore.

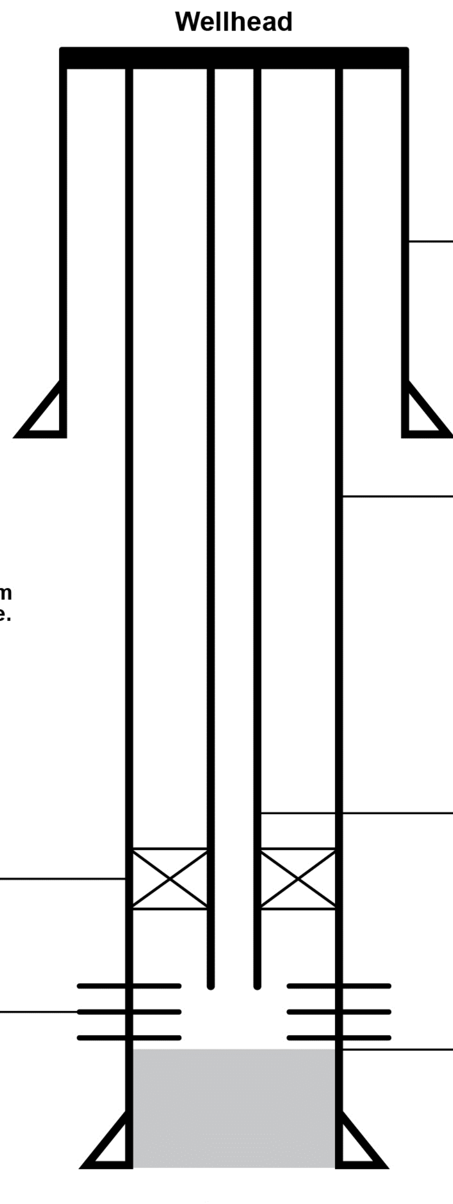
Well Preparation

All tubing and mechanical items should be removed from the well.

Logging Procedures

A baseline log is recommended for a class Ia well.

Appendix 4 Well Schematic



Base of groundwater protection
______mKB

Surface casing cement top
______mKB
______mTVD

Production casing cement top
______mKB
______mTVD

Caprock interval depth
______mKB
______mTVD

All hydrocarbon intervals (wet, tight, shale) to at least 200 m above the injection/disposal zone.
TD ____________m
PBTD ___________m
TD ____________m
PBTD ___________m
TD ____________m
PBTD ___________m

Packer depth
______mKB
______mTVD

Injection interval depth
______mKB to ______mKB
______mTVD to ______mTVD

TD
______mKB
______mTVD

KB elevation
______m

Surface casing
OD size __________mm
Weight ___________kg/m
Grade ___________
Depth ___________mKB
___________mTVD

Production casing
OD size __________mm
Weight ___________kg/m
Grade ___________
Depth ___________mKB
___________mTVD
Burst_____________kPa
Collapse__________kPa

Tubing
Size _____________mm
Weight ___________kg/m
Grade ___________
Depth ___________mKB
___________mTVD

PBTD

KB = kelly bushing	TD = total depth
mKB = metres below kelly bushing	TVD = true vertical depth
OD = outside diameter	PBTD = plugback total depth