DACC

DRILLING AND COMPLETION COMMITTEE

IRP 24: Fracture Stimulation

An Industry Recommended Practice (IRP) for the Canadian Oil and Gas Industry

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CAODC — Canadian Association of Oilwell Drilling Contractors

CAPP — Canadian Association of Petroleum Producers — Canada's Oil and Natural Gas Producers

EPAC — Canada's Oil & Gas Entrepreneurs™

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This IRP is a set of best practices and guidelines compiled by knowledgeable and experienced industry and government personnel. It is intended to provide the operator with advice regarding the specific topic. It was developed under the auspices of the Drilling and Completions Committee (DACC).

The recommendations set out in this IRP are meant to allow flexibility and must be used in conjunction with competent technical judgment. It remains the responsibility of the user of this IRP to judge its suitability for a particular application.

If there is any inconsistency or conflict between any of the recommended practices contained in this IRP and the applicable legislative requirement, the legislative requirement shall prevail.

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24.0 Preface

24.0.1 Purpose

This document contains a collection of Industry Recommended Practices (IRPs) to ensure that industry supported guidelines to manage subject well integrity, interwellbore communication and surface operations during fracture stimulation operations are available for relevant organizations and personnel. It may be used as a reference for the intended audience (see Audience), act as a guideline for Operators and Service Companies, or support the development of internal procedures for safe fracture stimulation practices.

There are two types of statements that relate to IRP compliance:

(1) REG statements
REG statements include "must" as a verb and are supported and linked to related regulations. Compliance to REG statements is mandatory according to jurisdictional regulations.

(2) IRP statements
There are two levels of IRP statements that indicate the fracture stimulation industry's support of a particular practice: "shall" and "should". Although compliance to IRP statements is optional, a broad representation of the fracture stimulation community in Western Canada developed, and support, these recommended practices.

Throughout this document the terms "must", "shall", "should", "may", and "can" are used within the document as outlined below. "Must" and "shall" statements are formatted as IRP statements. "Shall" statements are in bold. "Should" statements are not bold to more easily distinguish them from the "shall" statement:

Must	**A specific or general regulatory and /or legal requirement**
Shall	**An accepted industry practice or provision that the reader is obliged to satisfy to comply with this IRP**
Should	A recommendation or action that is advised and supported by industry
May	An option or action that is permissible within the limits of the IRP
Can	A possible action or capability within the context of the IRP

Regulators from Alberta, British Columbia, Saskatchewan, Manitoba, and the National Energy Board regularly attended committee meetings, had opportunity to comment on all drafts, and offer agreement in principle. With support of the fracture stimulation community along with significant representation from provincial regulatory bodies, the IRP 24 Committee believes this compilation of recommended practices represent the approach of a progressive and collaborative fracture stimulation industry committed to identifying preventative measures that minimize the risk of a loss of subject well integrity, minimize the risk of an interwellbore communication well control event and minimize surface risk during fracture stimulation operations.

If an Operator is using alternatives not expressed explicitly in this IRP, Operators ought to consider an equivalent degree, or higher degree, of safety and technical integrity as the actions stated in this IRP.

If there is any inconsistency or conflict among any of the recommended practices contained in this IRP and the applicable legislative requirements, the legislative requirement prevails.

It is the reader's responsibility to refer to the most recent edition of this document, all regulations and supporting documents.

This publication was produced in Alberta and emphasizes provincial legislation; however, all operations must adhere to jurisdictional regulations. A full disclaimer is noted on the inside cover of this document.

24.0.2 Audience

This document is primarily intended for the fracture stimulation sector of the oil and gas industry and, more specifically, well planning and completions personnel. It assumes the reader has a working knowledge of fracture stimulation operations. Organizations involved in fracture stimulation may find all or some portions of this IRP of interest.

24.0.3 Scope

The intention of this document is to provide recommended practices to determine risk, assess risk, minimize risk and carefully design control measures to an acceptable level. Application of the practices in this document is intended to reduce the risk of well control events and surface incidents resulting from fracture stimulation operations.

This document was developed primarily for the Western Canadian Sedimentary Basin. The IRP document was originated in Alberta, therefore, only regulatory requirements for the province of Alberta are directly referenced. Jurisdictional regulations apply.

The document does not specifically account for unique circumstances beyond British Columbia, Alberta, and Saskatchewan. During development of the document, interest and participation did extend beyond Western Canada (AB, BC, SK) to include operators and regulators in Manitoba as well as representation from the National Energy Board.

The document is structured around the *Fracture Stimulation Hazard Management Process* (FSHMP). The FSHMP is intended to offer a general, high level, iterative planning process typical to most fracture stimulation operations. It was developed collaboratively by a diverse group in the IRP 24 Committee and its working groups. Operator-specific and Service Provider-specific processes may diverge from the FSHMP presented here.

This Industry Recommended Practice is comprised of four chapters: *Fracture Stimulation Overview*, *Subject Well Integrity*, *Interwellbore Communication* and *Surface Operations.*

The *Fracture Stimulation Overview* introduces the document and the risk-based approach carried throughout the chapters. It describes the interrelationships among the three topical chapters and highlights topics that ought to be considered as early in the planning process as possible.

Subject Well Integrity considers downhole fracture stimulation concerns at the subject well for the fracture stimulation operation only. It does <u>not</u> explore fracture stimulation well design or discuss subject well integrity regarding well construction. It includes all downhole equipment up to the fracture treatment iron connection. This chapter offers an assessment methodology to iteratively analyze subject well integrity in order to determine subject well controls that support subject well containment during the fracturing operation.

The discussion in *Interwellbore Communication* is intended to minimize the risk of well control events due to interwellbore communication between an offset well and a subject energy well as the result of fracture stimulation operations. This chapter presents a process to determine at-risk offset wells, complete a barrier envelope analysis and adapt well control planning appropriately.

The *Surface Operations* chapter initiates assessment at the fracture iron where the fracturing iron starts and *Subject Well Integrity Assessment* ends. This chapter determines safety areas, hazard areas, elevated hazard zones, concurrent operations and special considerations locations. It incorporates the hazard register to identify hazards and reviews considerations for hazard management planning and wellsite execution.

24.0.4 Revision Process

Industry recommended practices (IRPs) are developed by the Drilling and Completions Committee (DACC) with the involvement of both the upstream petroleum industry and relevant regulators. IRPs provide a unique resource outside of direct regulatory intervention.

Technical issues brought forward to the Drilling and Completions Committee (DACC) as well as scheduled review dates can trigger a re-evaluation and review of this IRP, in whole or in part. For details on the specific process for the creation and revision of IRPs, visit the Enform website at www.enform.ca.

24.0.5 Sanction

The following organizations have sanctioned this document:

- Canadian Association of Oilwell Drilling Contractors (CAODC)
- Canadian Association of Petroleum Producers (CAPP)
- Explorers & Producers Association of Canada (EPAC)
- Petroleum Services Association of Canada (PSAC)

24.0.6 Acknowledgements

The amount of time and effort voluntarily contributed by the Co-Chairmen and Subject Matter Experts cannot go unrecognized. In a 4-year period our Committee, which at times swelled to over 120 participants, represented over 45 organizations, and six regulatory bodies. Together we were able to envision, develop and mutually agree to this technical discussion on fracture stimulation.

The project was led by set of dedicated Co-Chairmen selflessly carrying the torch, and occasionally rowing the boat, until circumstances required a hand-over. Jeff Saponja (nee TriAxon Oil Corporation) and Ron Gusek (nee Sanjel) kept us on course through the rapid development of the first stage of the IRP, Interwellbore Communication. Following sanction of Interwellbore Communication, Ron Gusek continued the journey and was joined by Dean Tymko (nee Penn West Petroleum Ltd.). Ron handed his torch and oars to colleague James Gray. James and Dean captained our quest through to the industry review. Dean tossed his oars and torch to Kevin Matiasz (nee Encana) who helped us sail through to the last leg.

From start to finish Camille Jensen stood firm in the role of helmsman and acted as our technical writer. Manuel Macias and Andy Reimer at Enform provided an anchor and kept us afloat by administering the project.

There were several key individuals that comprised our development team and our review teams. This project would have been impossible without the following great minds that joined us at the work group table regularly[1]: Alexey Zhmodik, Schlumberger; Barry Hlidek, Baker Hughes; Clint Olmstead, Conoco Phillips; Dan Belczewski. Bissett Resource Consultants Ltd.; Dean Tymko, Penn West Petroleum Ltd.; Dean Hillenga, Millennium Stimulation Services; Doug Pipchuk, Schlumberger; Eric Tudor, GasFrac; Fred Boyko, Schlumberger, Garnet Olsen, Canyon Technical Services; Greg Brown, Gasfrac; James Gray, Sanjel; Jonathan Heseltine, C-Fer Technologies; John McNaughton, Trican Well Services; Kevin Matiasz, Encana; Kyle Pisio, Canadian Natural Resources Ltd.; Mark Willis, Canadian Natural Resources; Marty Muir, Husky Energy Inc.; Mike Langill, Nabors Well Services Canada Ltd.; Rick Theissen, Conoco Phillips Canada; Ron Saunders, Imperial Oil Resources; Ryan McDowell, Crescent Point Energy Trust; Stacey Yuen, C-Fer Technologies; Steve Mueller, Birchcliff Energy;

Thank you to the employers of all our Subject Matter Experts. Your support in sharing your technical leaders, your meeting rooms, and dedicated presence through the development and review process did not go unnoticed and is representative of your support for the project and its published recommended practices. We would like to extend our appreciation to FMC Technologies and Sanjel Corporeation for the use of their Board Rooms for regular Committee meetings. We appreciated these rooms were well appointed, centrally located and offered our group a neutral place for open discussion.

Finally, we would like to thank the Drilling and Completions Committee for creating the space in the industry that allows for this collaborative and open forum. The development of IRPs is one of few venues where leading experts can work together to elevate their professional practice in a meaningful way.

[1] Many of these individuals have shifted employment. This list represents their sponsoring organization during their time on the IRP.

24.1 Fracture Stimulation Overview

The fracture stimulation industry has rapidly matured in the past decade. Multi-well pads with multi-stage fracture operations are now the norm. Pressure to reduce pad sizes yet increase production potential has created congestion on the surface for workers and saturated downhole activity in a confined area.

This Industry Recommended Practice presents a process and set of recommendations to thoroughly review, assess and develop controls to minimize risk, downhole and onsite, during fracture stimulation operations. It is the work of a group of fracture stimulation experts across Western Canada. Over 80 committee members representing 30 organizations including Operators, Service Companies and Regulators shared their expertise over three years to collaboratively develop this consensus-based document. It is the intention of the IRP 24 Committee that the process presented here be the baseline for fracture stimulation operations in Western Canada.

24.1.1 Approach

The IRP 24 Committee advocates for a philosophy of safety through shared knowledge to elevate industry acceptable practice in the fracture stimulation industry. The IRP 24 Committee believes that the best way to reduce the risk of a well control event or surface incident is through mindful planning and carefully designed control measures that reduce risk to an acceptable level. Therefore, IRP 24 has adopted a risk-based approach illustrated through the *IRP 24 Fracture Stimulation Hazard Management Process (FSHMP).* The FSHMP is an all-encompassing process that includes subject well integrity, interwellbore communication, and surface operations pertinent to the fracture stimulation industry.

As a risk-based document IRP 24 advocates for the concept of “as low as reasonably practicable”, or ALARP. ALARP is an approach to reduce risk to a point where risk is acceptable by applying control measures. The balance between risk mitigation and risk exposures is referred to as risk tolerance. The equilibrium point in that balance is ALARP. Operators are encouraged to review and determine their organization’s risk tolerance for planned fracture stimulation operations.

For more detail visit the United Kingdom HSE (Health Safety Environment) website for an industry guide: http://www.hse.gov.uk/risk/theory/alarpglance.htm.

24.1.2 Fracture Stimulation Hazard Management Process

The *Fracture Stimulation Hazard Management Process (FSHMP)* proposes a methodology of due diligence for Operators and Service Providers to consider in the planning, execution, and post-operational stages of a fracture stimulation operation (see Figure 1). It is an iterative process built to accommodate change as the project evolves and designed to align with the IRP document and its IRP statements. The *FSHMP* is divided into three columns that mirror chapters of this document: *Subject Well Integrity*, *Interwellbore Communication*, and *Surface Operations*. Details on the process specific to each chapter are in the related chapter.

Note. The *IRP 24 FSHMP* is not intended to replace existing organizational risk assessment processes and associated risk analysis tools or registers, nor is it intended to provide a complete risk analysis tool for organizations. Established Operators may use the *IRP 24 FSHMP* and *IRP 24 Hazard Register* to augment existing processes and tools. Newer entrants may use the *FSHMP* and *Hazard Register* as a basis for new processes and tools. Regardless how an organization chooses to implement the *FSHMP* and *Hazard Register*, the IRP 24 Committee supports and recommends that both documents be implemented in the planning stages of a fracture stimulation operation.

The FSHMP begins with the assumption that fracture stimulation design has been established. Change management and lessons learned through the process may triggers modifications in the fracture stimulation design and are represented in the figure by the orange rectangle and the red ellipse respectively.

24.1.2.1 Change Management

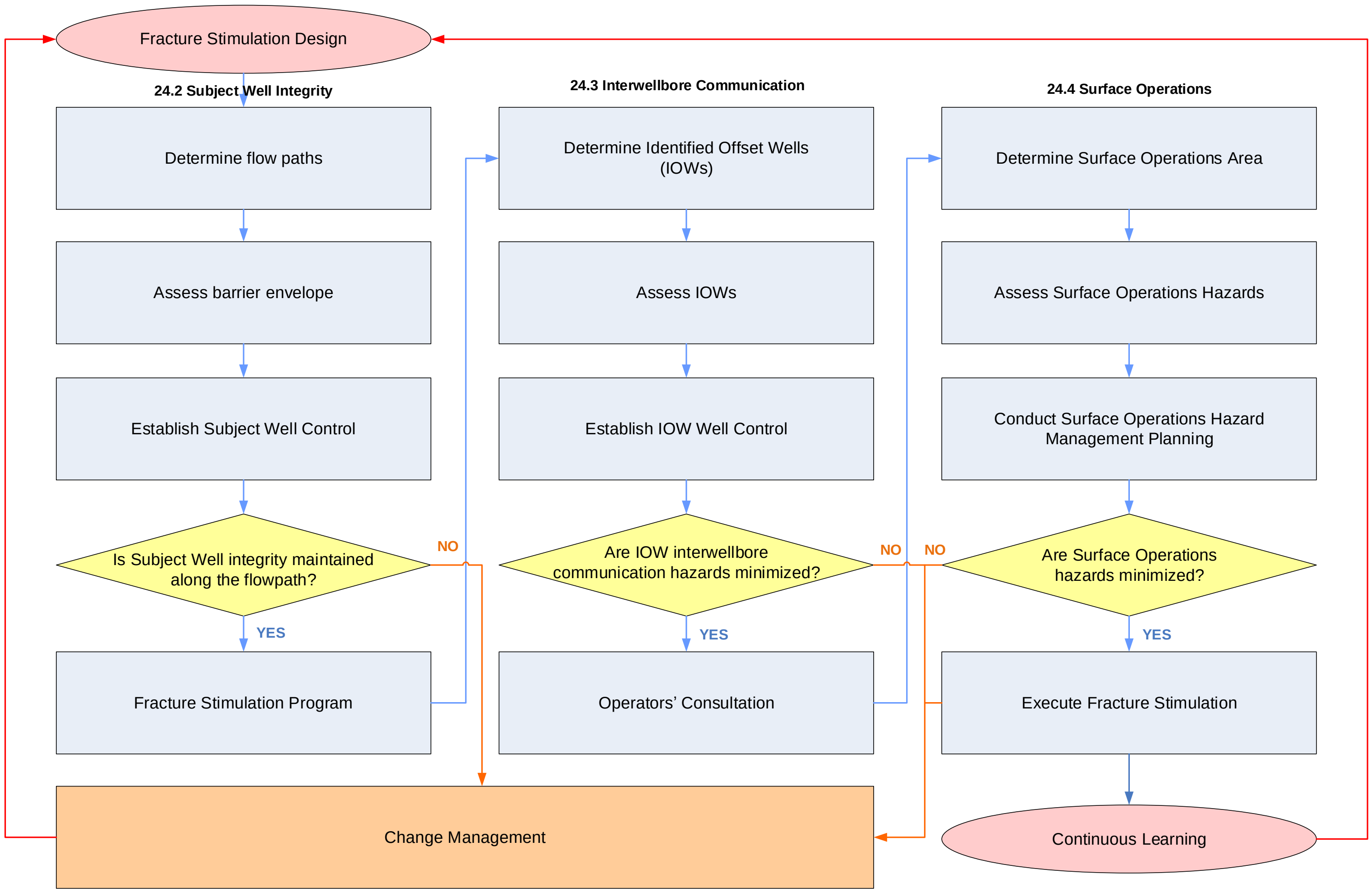
Once a fracture stimulation operation has commenced, operational plans, can and often do, change. It is imperative to re-evaluate subject well integrity, interwellbore communication and surface operations hazards when operational plans change.

The questions posed in the yellow diamonds on the FSHMP figure below may trigger change management.

24.1.2.2 Continuous Learning

The conclusion of a fracture stimulation operation is an opportunity to gather data, document findings and debrief the operation for future fracture stimulation operations. Operators are encouraged to include continuous learning activities as part of their operating practices.

Figure 1. Fracture Stimulation Hazard Management Process



24.1.3 Hazard Register

The Hazard Register is a document separate from the IRP that allows the reader to put the recommendations stated here into practice. It documents known hazard scenarios experienced at the time of, or before, the writing of this IRP 24. (**Note**. The IRP 24 Hazard Register is not an exhaustive listing and should not be considered so).

The IRP 24 Hazard Register is available for download at the IRP 24 landing page:

http://www.enform.ca/resources/detail/29/dacc-irp-volume-24-fracture-stimulation

Each chapter in this document includes an assessment: subject well barrier envelope, identified offset wells, and surface operations hazards. Within each of these assessments the reader is encouraged to review the IRP 24 Hazard Register to assure industry known hazards have been appropriately reviewed and controlled.

The Hazard Register is not intended to replace existing operational processes or tools, rather to act as a cross-reference of industry known hazard scenarios against Operator or Service Provider specific assessments. Established Operators are encouraged to integrate the IRP 24 Hazard Register to augment existing processes and tools. Newer entrants may employ the Hazard Register as a basis for new process and tools.

IRP The Operator shall employ the content of the IRP 24 Hazard Register or integrate IRP 24 known hazard scenarios into existing organizational risk assessment processes to identify additional risk assessment considerations.

The purpose of the IRP 24 Hazard Register is to:

- provide a shared location for industry identified hazard scenarios and associated risk severity,
- facilitate operational planning by providing potential options to minimize risk and determine appropriate controls,
- establish a baseline and industry standard for risk tolerance, and/or
- provide a mechanism for contingency planning and development of site-specific control measures.

The IRP 24 Hazard Register is a living document to be updated regularly by industry experts. As experts experience new hazard scenarios and develop new controls or mitigations, these hazard scenarios may be documented in the IRP 24 Hazard Register for industry-wide use. The IRP 24 Committee invites organizations to share lessons learned and additions to the Hazard Register.

The IRP 24 Committee strongly encourages all affected stakeholders forward any hazard scenarios not identified in the IRP 24 Hazard Register to Enform.

24.1.4 Planning Challenges

Today's fracture stimulation operations are complex operations that create spacing challenges, concerns with concurrent operations and require particular attention to shallow operations. Operators are encouraged to review the topics presented below as early in the planning stages as possible.

24.1.4.1 Lease Spacing

It is desirable to limit pad size, which creates a challenge in lease spacing; therefore, facility and equipment spacing is best determined early in the planning stages. Refer to *IRP 20: Wellsite Design Spacing Recommendations* for general spacing recommendations. Additionally, consider the following before fracture stimulation operations begin:

- Spotting the lease
  - Locate fracture stimulation operations on the lease, then
  - Evaluate if the lease is able to accommodate the planned fracture stimulation operation
- Spacing between operations
- Spacing existing wells

Spacing needs may require modification to Subject Well parameters, the fracture stimulation program, or where possible, the lease layout.

24.1.4.2 Concurrent Operations

With an increase in multi-well and multi-stage fracture operations there is an increase in the likelihood of concurrent operations occurring on the lease. Concurrent operations refer to any operation not associated with the current fracture stimulation operation, and occurring in close proximity to the Subject Well.

Concurrent on-lease downhole operations expected during fracture operations are considered Identified Offset Wells (IOWs) and assessed during the IOW Risk Assessment (see 24.3.3).

Surface concurrent operations within hazard areas are discussed in 24.4.2.3.

IRP The Subject Well Operator shall identify and anticipate concurrent operations in the planning stages.

24.1.4.3 Shallow Well Fracture Stimulation

Fracture stimulation operations near the top of bedrock or base of groundwater may result in a release of fluids to the surface. AER's *Directive 083* regulates these operations.

Fracture stimulation operations near the top of bedrock or base of groundwater may result in a release of fluids to the surface, contamination of non-saline aquifers as well as breach of the containment mechanism leading to loss of reserves.

REG The Operator must adhere to *Directive 083: Hydraulic Fracturing – Subsurface Integrity* (or relevant jurisdictional regulations) to prevent surface impacts, contamination of non-saline aquifers and reserves impacts when fracturing near the top of bedrock.

24.1.4.4 Monitoring and Reporting Induced Seismicity

"Seismicity is a recorded earthquake caused primarily by fault movement, typically referring to events greater than a 0.5 magnitude. Induced seismicity is an event resulting from human activity, and can be caused by industries such as mining and natural gas development.[2]" Anomalous induced subsurface seismic events from energy related activities have been observed since the 1960s.

Alberta regulatory bodies are actively investigating the relationship between fracturing operations and seismic events.

> "Since 2008, the AER, through the Alberta Geological Survey (AGS), has been directly monitoring natural seismicity levels in Alberta and assessing subsurface energy resource operations (mainly completion activities such as hydraulic fracturing) for potential links to induced seismicity. In those efforts, the AER and AGS have been working alongside federal and university researchers to understand the links between new energy development and risks associated with induced seismicity.[3]"

There have been "observed unexpected persistent patterns of seismic events above background levels west of the community of Fox Creek, Alberta.4" Monitoring and reporting of seismic activity is required in the Fox Creek area particularly regarding the Duvernay Zone.

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[2] BCOGC (2015). Defining: Induced Seismicity.

[3] AER (2015). Subsurface Order No. 2: Monitoring and Reporting of Seismicity in the Vicinity of Hydraulic Fracturing Operations in the Duvernay Zone, Fox Creek, Alberta

[4] AER (2015). Subsurface Order No. 2: Monitoring and Reporting of Seismicity in the Vicinity of Hydraulic Fracturing Operations in the Duvernay Zone, Fox Creek, Alberta

REG Operators with completions within the specified zone must comply with *AER Subsurface Order No. 2*.

REG Fracture stimulation operations in BC must comply with the BC Oil and Gas Activities Act, *Drilling and Production Regulation, 21.1 Induced seismicity regulation*.

There are several industry and regulatory resources that discuss induced seismicity.

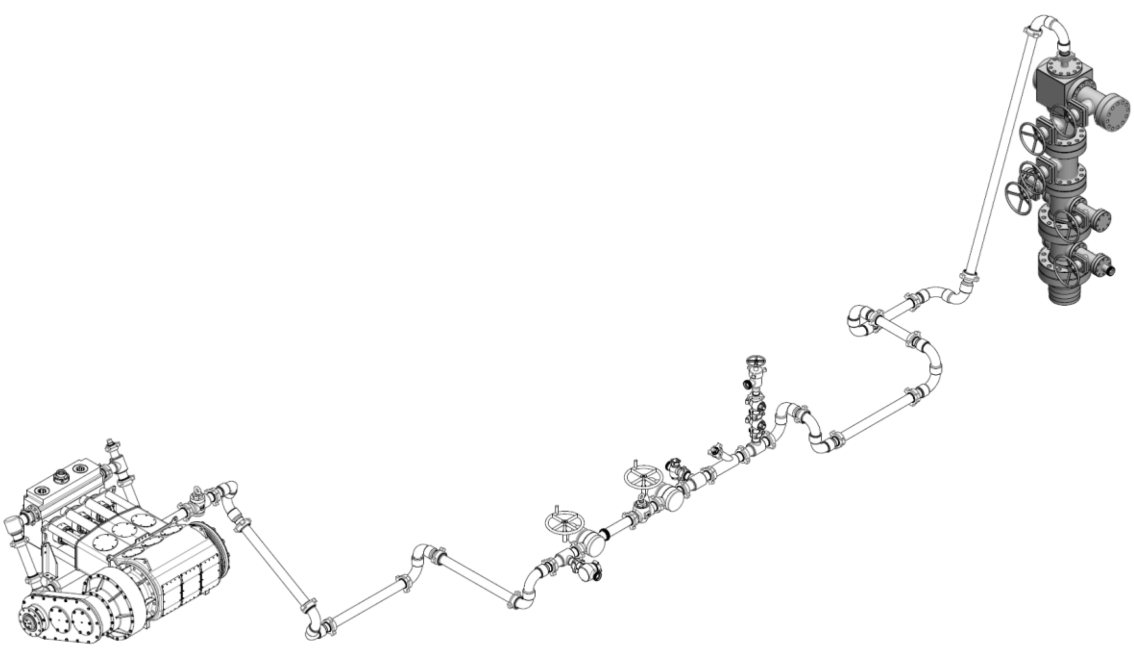
- *AER (2015). Subsurface Order No. 2: Monitoring and Reporting of Seismicity in the Vicinity of Hydraulic Fracturing Operations in the Duvernay Zone, Fox Creek, Alberta*
- *BCOGC (2015). Defining: Induced Seismicity*
  - The following studies are referenced in *Defining: Induced Seismicity*:
    Investigation of Observed Seismicity in the Montney Trend (December 2014)
    Investigation of Observed Seismicity in the Horn River Basin (August 2012)
- *CAPP Hydraulic Fracturing Operating Practice: Anomalous Induced Seismicity: Assessment, Monitoring, Mitigation and Response.*

24.2 Subject Well Integrity

Subject Well Integrity, as discussed in this document, explores downhole fracture stimulation concerns at an existing Subject Well. Discussion in this document assumes there is a fracture stimulation design in place for an existing Subject Well. In all new wells, the well design and casing should be chosen based on all activities expected through the life of the well.

This chapter does not explore fracture stimulation well design or discuss subject well integrity regarding well construction. The discussion does consider all downhole equipment up to the fracture iron (see the grey shaded area in Figure 2 below). The document explores the relationship between fracture stimulation design and the subject well barrier envelope limitations to adjust either subject well control or the fracture stimulation design.

Figure 2. Subject Well Integrity includes all subsurface equipment for the well to be fracture stimulated in addition to surface equipment on the well (shaded below) up to the connection to the frac iron (not shaded below) which is covered in the Surface Operations Chapter.



This chapter presents a process to assess the Subject Well and develop an appropriate fracture stimulation program. Chapter 24.3 Interwellbore Communication continues on to explore communication issues between the Subject Well and an offset well. Chapter 24.4 Surface Operations continues where the fracture iron meets the wellhead.

A subject wellbore with sound wellbore integrity ensures fracture placement reaches the expected target formation while containing fluids associated with the fracturing operation within the wellbore. Subject wells intended for fracture stimulation often have temporary equipment installed (e.g., wellhead isolation equipment) during the completion phase to contain and manage high pressure stimulation operations. Typically, the highest internal pressure a Subject Well experiences occurs during the fracture stimulation, and is most likely the only time the Well may see such elevated pressures.

In addition to pressure, several fracture stimulation factors may compromise Subject Well integrity (see 24.2.3.2). Subject Well controls are vital for maintaining Subject Well integrity during fracture stimulation operations. (Recommendations for cementing wells are available in *IRP 25: Primary and Remedial Cementing Guidelines*.)

IRP The Subject Well Operator shall be responsible for minimizing the risk of fracture stimulation operations causing a well control event at the Subject Well.

REG If a well control event occurs or subject well integrity fails, the Subject Well Operator must notify as per *Directive 083: Hydraulic Fracturing – Subsurface Integrity* or in accordance with relevant jurisdictional regulations.

There are two principle means for minimizing the risk of the loss of subject well integrity at a Subject Well:

1. Adjust the Fracture Stimulation Design.
2. Design/modify appropriate Subject Well controls by using the Subject Well Integrity Hazard Management Process (see Figure 2).

24.2.1 Subject Well Integrity Hazard Management Process

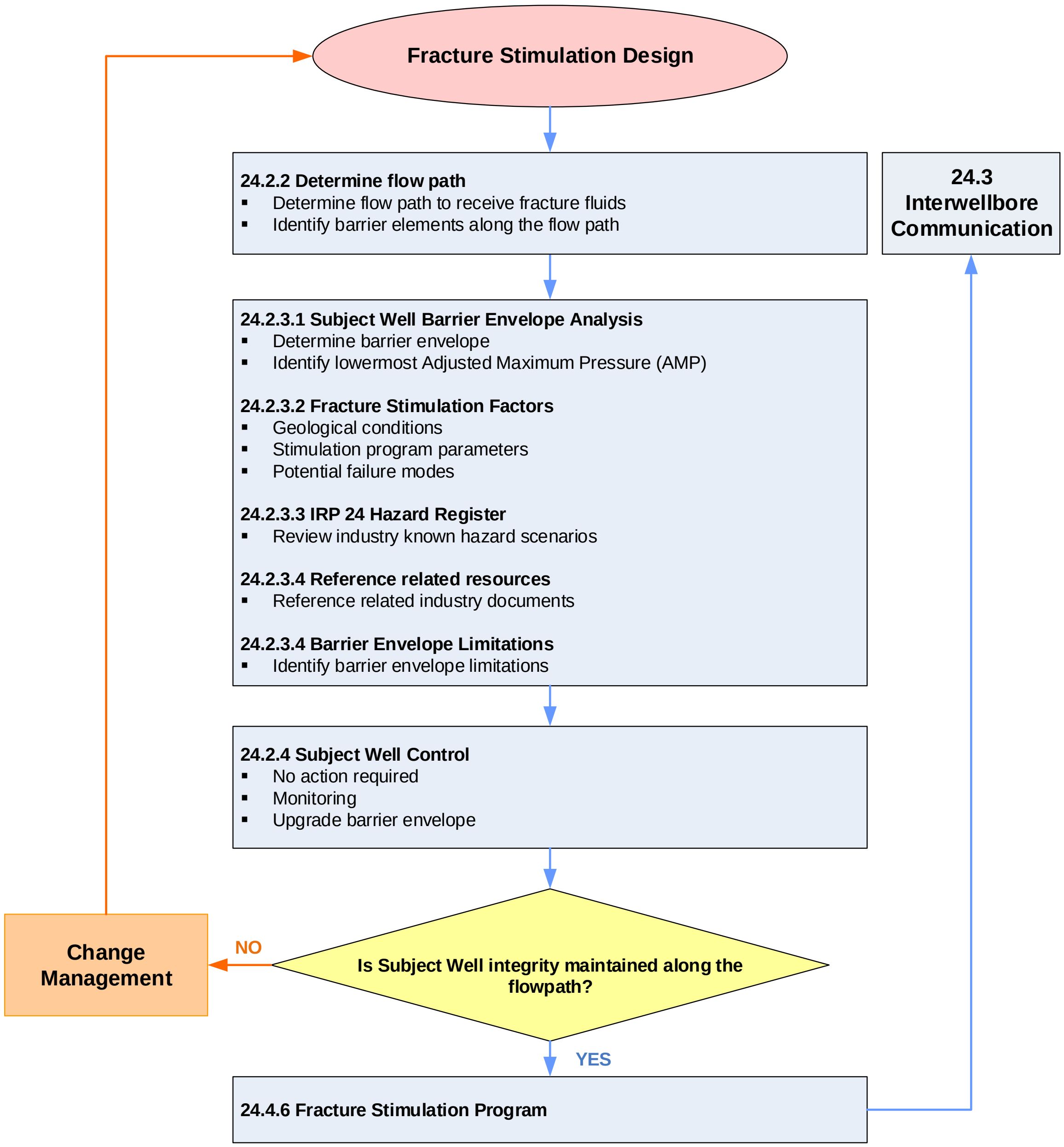
The *Subject Well Integrity Hazard Management Process (SWIHMP)* is part of the larger Fracture Stimulation Hazard Management Process *(FSHMP)*. The FSHMP proposes a methodology of due diligence for Subject Well Operators to consider in the planning, execution, and post-operational stages of a fracture stimulation operation.

The SWIHMP provides a set of recommended practices for the Subject Well Operator to complete a Subject Well Integrity Assessment and address Subject Well Controls appropriate for the fracture stimulation operation.

This document assumes that a *fracture stimulation design* is in progress, and a maximum treatment pressure is in place before the Subject Well Integrity Assessment commences. The fracture stimulation program may evolve through iterations within the Fracture Stimulation Hazard Management Process.

Figure 3 illustrates the *Subject Well Integrity Hazard Management Process* chronologically and in relation to the sections of this document. The diagram begins with a pink ellipse that notes the assumption of beginning the SWIHMP with fracture stimulation design in progress. Next process boxes (in blue) are aligned with corresponding section headers in this chapter. The bullet points in each process box summarize key elements in the related section. A decision point box is noted with a yellow diamond and change management is in an orange box. The pink box indicates how the *Subject Well Integrity Hazard Management Process* links on to the next stage, *Interwellbore Communication Hazard Management Process* detailed in Chapter 3.

Figure 3. Subject Well Integrity Hazard Management Process.



24.2.2 Determine Flow Path

Based on the preliminary fracture design, first determine the flow path expected to receive fracture fluids (casing, tubing, liner, coiled tubing, an annulus or some combination). The flow path is the conduit that will deliver fracturing fluids from the surface to the intended target formation.

Once the flow path is determined, identify the barrier envelope that contains the flow path. This barrier envelope is evaluated during the following subject well integrity assessment.

24.2.3 Subject Well Integrity Assessment

Subject Well Integrity Assessment sets the framework for evaluating the current Subject Well Barrier envelope expected to receive and contain fracture fluids. The Subject Well barrier envelope refers to one or more barrier elements that prevent fluids from flowing unintentionally from the formation into the wellbore, into another formation or to the external environment.

A barrier element refers to an individual equipment component or objects that together collectively comprise a barrier envelope. A barrier element as an object alone cannot prevent flow from one side to the other side of itself. A barrier envelope configured to contain fracture fluids will maintain subject well integrity through the fracture stimulation operation.

Fracture stimulation operations may occur on new or existing wells. In both cases a well barrier envelope is already in place before fracture operations begin, but may not be specifically designed to contain the planned fracture stimulation program. Therefore, the existing well barrier envelope requires an assessment to analyze its effectiveness to withstand the fracture stimulation operation and determine if mitigation measures are required.

Effective subject well integrity assessment first determines the expected flow path for the fracture fluids. Then, it analyzes incompatibilities between barrier elements and the fracture stimulation factors, and cross-references with the IRP 24 Hazard Register. The final step in the assessment considers the limitations of barrier elements collectively as an envelope against fracture stimulation factors and site-specific hazard scenarios.

Fracture stimulation subject well integrity assessment is organized into four parts:

1. Subject Well barrier envelope analysis
2. Fracture stimulation factors
3. IRP 24 Hazard Register
4. Barrier envelope limitations

24.2.3.1 Subject Well Barrier Envelope Analysis

The barrier envelope analysis assesses each barrier element along the expected flow path to establish the barrier envelope Adjusted Maximum Pressure (AMP). The barrier envelope AMP is the lowermost AMP of all the barrier elements within the envelope(s).

IRP The Subject Well Operator shall determine the Subject Well barrier envelope(s) AMP.

A recommended Subject Well barrier envelope analysis consists of three steps:

Step 1. Determine the envelope(s) (primary and secondary, if applicable). A barrier envelope represents all the barrier elements that are dependent on each other for collectively containing the flow of fracture fluids. These may be illustrated on a barrier schematic. Appendix A offers sample schematics for a stimulation operation through casing and through a fracture string, respectively.

Step 2. For each barrier element determine the Adjusted Maximum Pressure (AMP). Review barrier element / connection design and installation. The AMP is determined by analyzing a barrier element's Original Equipment Manufacturer's (OEM) specification/rating and then reducing this original pressure rating to compensate for the service factors affecting barrier performance. (See Appendix B for an expanded discussion of burst and collapse considerations as well as Barrier Element AMP Calculations.)This adjusted pressure is determined at the Subject Well Operator's discretion, is to be in alignment with the Subject Well Operator's risk tolerance, and must meet regulatory requirements such as AER Directive 010 minimum casing design requirements.

Step 3. Establish the envelope AMP by identifying the barrier element that has the lowermost AMP. The barrier envelope AMP is defined by the lowermost barrier element AMP. That barrier element AMP is assessed against fracture stimulation factors and the Hazard Register to determine barrier envelope limitations. (See Appendix B, Barrier Envelope Calculations, for suggested calculations to understand existing well envelope burst and collapse.)

Step 4. Assess groundwater protection at the Subject Well.
Note. If the barrier analysis reveals groundwater protection concerns at the Subject Well that cannot be remediated by upgrading the barrier envelope, then it is imperative to revisit the fracture stimulation design. Prior to fracture stimulation, the Subject Well Operator may consider baseline water well testing.

24.2.3.2 Fracture Stimulation Factors

With the barrier envelope AMP in mind, the most concerning fracture stimulation factors can be identified. There are several factors to consider that can influence subject well integrity during the fracture stimulation operation. These factors can generally be grouped as geological conditions, fracture stimulation parameters and potential failure modes.

IRP The Subject Well Operator shall identify fracture stimulation factors that can compromise Subject Well barrier envelope(s).

Subject well barrier fracture stimulation factors may include, but are not limited to the following:

Geological conditions

- fault analysis
- high permeability streaks
  - natural fractures
  - conglomerate intervals
- bounding layers
- reservoir parameters (e.g., pressure, temperature, H_2S, lithology, depth)

Stimulation parameters

- multistage method (e.g., ball drop, abrasive jet, plug-and-perf)
- fluid (e.g., system chemistry, type, volumes)
- proppant (e.g., type, size, concentrations, volumes)
- pumping (e.g., pressures, rates, schedule)
- $Burst\ Pressure_{max}$ and $Collapse\ Pressure_{max}$ (see Appendix B: Maximum Burst and Collapse Pressures for suggested calculations)

Potential failure modes

- erosion
- corrosion
- Sulfide Stress Cracking (SSC) (e.g., unacceptable axial or circumference stresses with respect to material exposed to sour fluids)
- excessive cyclic loading
- thermal loading
- mechanical loading (i.e., tri-axial stress)
- internal and external pressures
- inadequate cement hydraulic isolation
- out-of-specification well construction practices (e.g., connection over-doping, over-torque, under-torque)
- faulting-induced casing damage (see 22.1.4.4 Monitoring and Reporting Induced Seismicity)

24.2.3.3 IRP 24 Hazard Register

With regards to Subject Well integrity, the Hazard Register is intended as a tool for Operators to cross-reference industry known hazard scenarios against Operator-specific assessments. It may reveal the potential occurrence of a new hazard unfamiliar to the Subject Well Operator, but known to the industry.

IRP The Subject Well Operator shall employ the content of the IRP 24 Hazard Register or integrate IRP 24 known hazard scenarios into existing organizational risk assessment processes to identify additional risk assessment considerations.

24.2.3.4 Reference Related Resources

A review of relevant IRPs and guidelines may provide additional guidance. Examples may include the following:

- IRP 2: Completing and Servicing Critical Sour Wells
- IRP 5: Minimum Wellhead Requirements
- IRP 25: Primary and Remedial Cementing Guidelines

24.2.3.5 Barrier Envelope Limitations

There are three key pieces of information necessary to understand barrier envelope limitations: (1) the barrier envelope AMP, (2) concerning fracture stimulation factors, and (3) wellbore-specific hazards determined through the Hazard Register. The final step in the Subject Well Integrity Assessment is to analyze the interrelationship among these three to determine limitations of the Subject Well barrier envelope(s).

IRP The Subject Well Operator shall determine the limitations of the barrier envelope(s).

Barrier envelope limitations may include, but not be limited to, the following:

- expected pumping pressures greater than the barrier envelope AMP
- potential failure modes (see 24.2.3.2)

24.2.4 Subject Well Control

The resulting analysis from the Subject Well Integrity Assessment reveals the limitations in the existing Subject Well barrier envelope(s). Subject Well control establishes the mitigations and controls to minimize limitations determined in the subject well barrier analysis to an acceptable level. Ultimately, Subject Well control measures ensure that fracture placement reaches the expected target formation without a loss of subject well integrity.

IRP The Subject Well Operator shall implement Subject Well control practices based on the findings from a Subject Well Integrity Assessment.

Strategies and practices to maintain Subject Well containment are specifically selected based on Subject Well barrier envelope limitations. Since each well is unique, it is difficult to establish an exhaustive list of strategies and practices to assure subject well integrity. However, there are some common practices that begin by comparing barrier envelope AMPs to the fracture stimulation program.

24.2.4.1 No Action Required

If the limitation of the barrier envelope(s) is deemed high enough, then the barrier envelope(s) may not require any actions or may not need to be monitored during the fracture stimulation operation.

24.2.4.2 Monitoring

The Operator may decide that modifications to the barrier envelope can be triggered by closely observing the pressure and rate fracturing data for specific activity during the fracture operations. Monitoring may be selected as an appropriate well control practice when the Operator and Service Provider agree that modifications to control barrier limitations can be made during fraction operations.

24.2.4.3 Upgrade Barrier Envelope

When a primary barrier envelope AMP does not meet the fracture stimulation program (i.e., maximum treatment pressure), that barrier envelope needs to be upgraded. In the situation of a new drill, the Operator may choose to modify the casing design to a higher OEM specification. If the barrier envelope on a new drill cannot be upgraded, then the Operator may opt to isolate the casing with another barrier element (e.g., install a fracture string), or resolve to adjust the fracture stimulation program such that the Subject Well is able to maintain containment by the existing primary barrier envelope (e.g., reduce pump rates to lower maximum treating pressure).

24.2.5 Maintain Subject Well Integrity

With the Subject Well Control practices established, it is important to review the plan and contemplate if Subject Well integrity has been maintained along the expected fracture fluid flow path within the larger context of the Subject Well Integrity Hazard Management Process (SWIHMP) and the Fracture Stimulation Hazard Management Process (FSHMP). Does the combination of the expected flow path, barrier envelope limitations and the subject well control practices produce a degree of confidence that subject well integrity will be maintained? (This question aligns with the yellow diamond in the SWIHMP.)

If the Operator is confident that the planned controls and mitigations are within the Operator's risk tolerance and will minimize the risk of the fracture stimulation operation causing a well control event at the Subject Well, then the Operator can finalize the fracture stimulation program and continue on to interwellbore communication assessments.

If upon reflection in the larger context, the Operator is uncertain that the planned controls and mitigations will minimize the risk of a well control event, then the Operator needs to resolve why this may be the case. It may require the Operator review subject well integrity hazard management planning by revising the expected fracture fluid flow path (24.2.2) revisiting activities as part of the barrier envelope analysis (24.2.3.1), re-considering the barrier envelope limitations (24.2.3.4) and/or re-establishing subject well control practices (24.2.4). It could also require the Operator modify timing on concurrent operations, or it may require the Operator revisit the fracture stimulation design.

Only once the Operator has established a degree of confidence that the risk of a Subject Well control event has been controlled and mitigated within the Operator's risk tolerance may the Operator finalize a fracture stimulation program.

24.2.6 Fracture Stimulation Program

The fracture stimulation program is the document that defines the procedures and requirements to meet the Subject Well fracture stimulation design. The fracture stimulation program includes, but is not limited to the following parameters:

- flow path
- pressures
- base fluid types
- chemicals
- fluid rheology
- proppant type, size, concentration and tonnage
- rates
- volumes
- equipment
- method of controlling Maximum Surface Treating Pressure (STP_{max}) (see Appendix B)

24.3 Interwellbore Communication

This discussion on *Interwellbore Communication* is intended to minimize the risk of well control events due to interwellbore communication between an offset well and a subject energy well as a result of fracture stimulation operations. In some cases interwellbore communication can be planned to enhance reservoir stimulation. This chapter presents a process to determine at-risk offset wells, complete a barrier envelope analysis at an offset well and adapt well control planning appropriately for both planned and unplanned interwellbore communication.

Interwellbore communication may occur as a fluid and/or pressure communication event at an offset well resulting from fracture stimulation operation on the Subject Well. Interwellbore communication can lead to a *well control event*.

Typically, the highest pressure a Subject Well experiences occurs during fracture stimulation and is most likely the only time the well may experience such elevated pressures. Well designs often have temporary equipment installed (e.g., fracture stimulation packers, fracture stimulation tubing strings, tree savers) during the completion phase to contain and manage high pressure stimulation operations. Offset wells are most likely designed with wellbore integrity for its production phase and may require risk reduction measures if interwellbore communication is possible.

IRP The Subject Well Operator shall be responsible for minimizing the risk of interwellbore communication causing a well control event at an Identified Offset Well as a result of fracture stimulation operations at the Subject Well.

IRP If a well control event occurs at an Identified Offset Well, the Offset Well Licensee's Emergency Response Plan (ERP) shall be invoked.

REG If a well control event occurs or communication to an IOW occurs, the Subject Well Operator must notify as per *Directive 083: Hydraulic Fracturing – Subsurface Integrity* or in accordance with relevant jurisdictional regulations.

There are two principle means for minimizing the risk of interwellbore communication well control events at an Offset Well:

1. Adjust the Subject Well's parameters (see 24.3.5.1 Change Management).

2. Develop an appropriate Well Control Plan by using the *Interwellbore Communication Hazard Management Process* (see Figure 3).

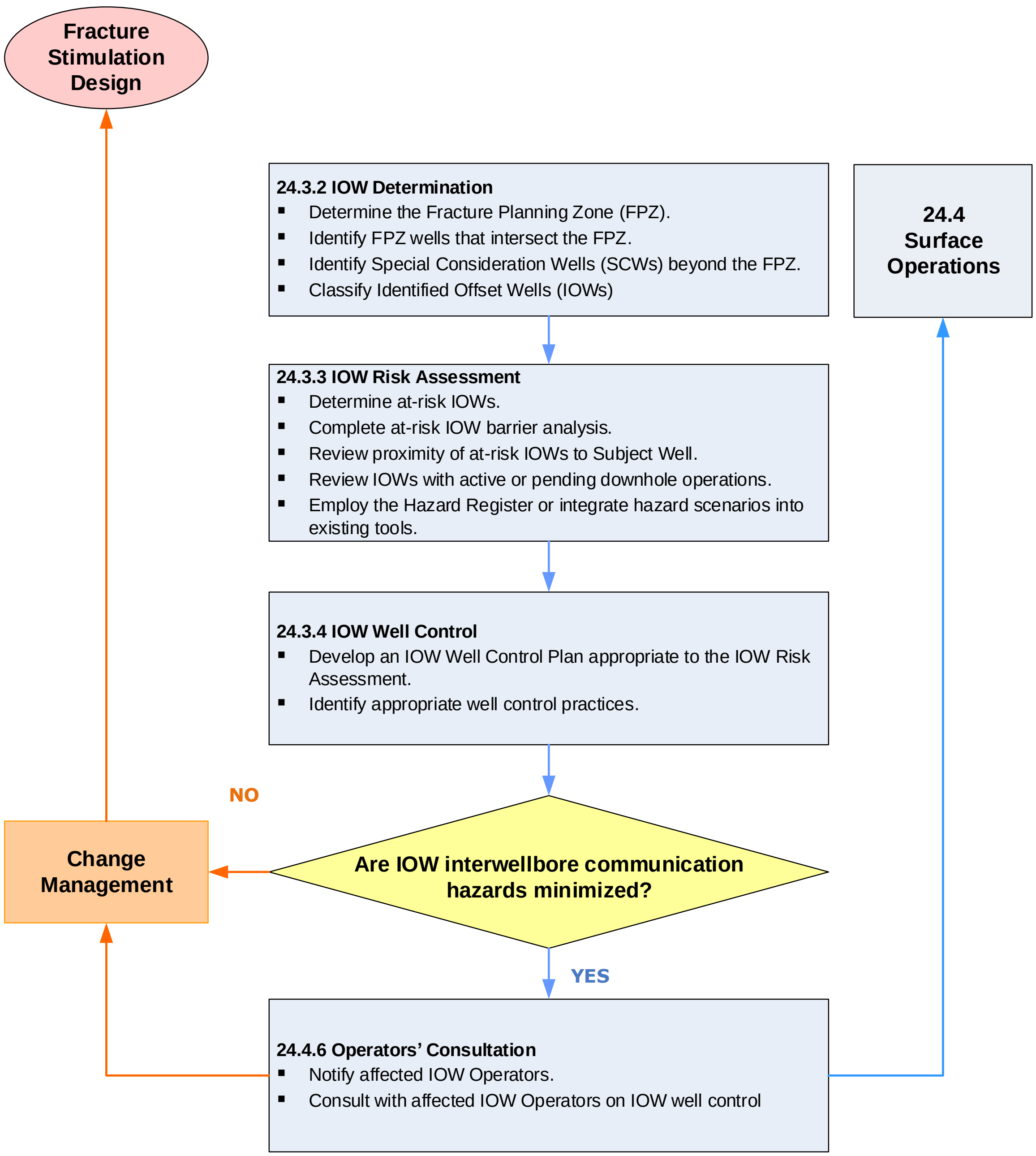
24.3.1 Interwellbore Communication Hazard Management Process

The *Interwellbore Communication Hazard Management Process (ICHMP)* is part of the larger *Fracture Stimulation Hazard Management Process* *(FSHMP).* The FSHMP proposes a methodology of due diligence for Subject Well Operators to consider in the planning and execution stages of a fracture stimulation operation.

The ICHMP suggests a process to identify offset wells proximal to the Subject Well that may be at-risk from the proposed fracture stimulation operation. It provides a set of recommended practices for both the Subject Well Operator and an Offset Well Operator to determine an appropriate well control plan for offset wells identified by the Subject Well Operator as “at-risk”.

Figure 4 illustrates the *Interwellbore Communication Hazard Management Process* in relation to the sections of this document. Process boxes (in blue) are aligned with corresponding section headers in this chapter. The bullet points in each process box summarize key elements in the related section. A decision point box is noted with a yellow diamond and change management is in an orange box.

Figure 4. Interwellbore communication hazard management process.



24.3.2 IOW Determination

Identified Offset Wells (IOWs) are all offset wells within the Fracture Planning Zone (FPZ) (see 24.3.2.1) plus all wells identified as Special Consideration Wells (SCW) (see 24.3.2.3).

These include all wells in any state, such as, but not limited to:

- licensed and not yet spud
- drilling
- completing or servicing
- cased and standing (e.g., well drilled but without a wellhead installed)
- openhole
- producing or injection
- shut-in or suspended
- abandoned in any form (e.g., cut and capped)
- orphaned (a well that has no legally responsible or financially able Operating Company)
- active operations (manned and unmanned)

IRP The Subject Well Operator shall determine a set of IOWs based on the Subject Well.

24.3.2.1 Fracture Planning Zone Determination

The Fracture Planning Zone (FPZ) defines a screening area around the Subject Well, making it possible to identify all offset wells proximal to the Subject Well that require risk assessment.

IRP The Subject Well Operator shall determine and map the FPZ using the following two steps:

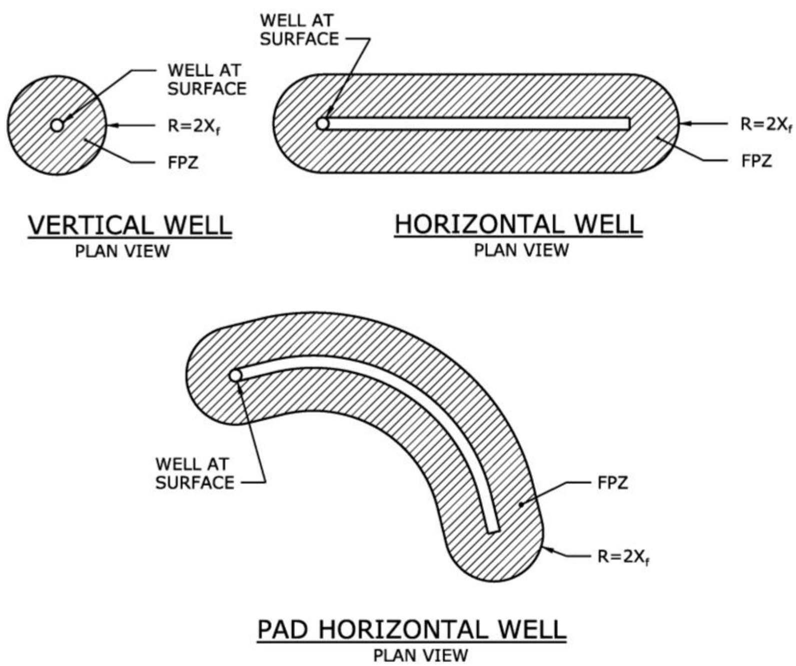
Step 1. Determine a fracture half-length value (X_f) for all fracture treatments that are proposed for the Subject Well based on operator experience (e.g., offset communication, fracture geometry diagnostics, model) or simulation.

The fracture half-length (X_f) is the lateral distance initiated from the Subject Well to the outer tip of a fracture propagated by fracture stimulation operations. The fracture half-length (X_f) is also the maximum extent of the influence of the subsurface interaction by an induced fracture. Creating a fracture model and/or simulation is one method to establish X_f. (See Appendix C: Modeling Fracture Half-Length.)

Step 2. Using the longest X_f determined in Step 1 draw the outer boundary of the FPZ equal to a distance $2X_f$ (twice the fracture half-length) from the wellbore around the plan view of the well (see Figure 5).

Note. Consider all possible fracture stimulation initiation points within the Subject Well in determining the FPZ. The value $2X_f$ is based on the possibility of a planar single-wing hydraulic fracture.

Figure 5. Top/Plan view of FPZ for a vertical, horizontal, and pad horizontal Subject Wellbore.



24.3.2.2 Fracture Planning Zone Well Identification

Once the FPZ is determined, identify and map each offset well that intersects the FPZ. Classify these as FPZ Wells.

IRP The Subject Well Operator shall identify all FPZ wells on a map.

24.3.2.3 Special Consideration Well Identification

Special Consideration Well (SCW) determination allows individual wells of concern to be included in the IOW Risk Assessment without expanding the FPZ. SCWs are any offset wells beyond the FPZ that have unique circumstances that may put that well at-risk and; therefore, require risk assessment.

Offset wells beyond the FPZ are classified as SCWs with some or all of the following criteria:

- historical experience
- estimation uncertainty when determining the FPZ (see Appendix C)
- fracture azimuth (consider surface and subsurface monitoring data such as microseismic data)
- geology (e.g., regions prone to natural faults and fractures)
- age and condition of the offset wellbore
- water well
- possible pressure communication
- wells with fracture half-lengths that may intersect the FPZ
- wells being drilled with planned trajectories that intersect the FPZ (not necessarily during fracture operations)

IRP The Subject Well Operator shall determine SCWs beyond the FPZ.

24.3.3 IOW Risk Assessment

With a clear set of IOWs identified (see 24.3.2 IOW Determination), IOW risk assessment sets the framework for the development of IOW Well Control Plans. Effective interwellbore communication risk assessment is a five-step process:

1. Determine at-risk IOWs.
2. Complete IOW barrier analyses for at-risk IOWs only.
3. Assess the probability of interwellbore communication in relation to IOW proximity to the Subject Well.
4. Identify IOWs with active downhole operations.
5. Employ IRP 24 Hazard Register content.

24.3.3.1 Determine At-Risk IOWs

Within the IOWs, there will be at-risk wells and wells that are minimal risk.

At-risk wells are:

- IOWs that penetrate or have hydraulic fracture geometry (consider lateral and vertical extension, see Glossary and 24.3.2 IOW Determination, Step 1) in the Subject Well target zone
- IOWs that terminate or have hydraulic fracture geometry near the Subject Well target zone

Minimal risk wells are determined according to the Subject Well Operator's risk tolerance may not require a barrier analysis and may not require any actions during the fracture stimulation operations. If an IOW is determined minimal risk, then it is recommended to document a rationale for classifying the well as minimal risk (see 24.3.4.1.1 No Action Required).

IRP The Subject Well Operator shall identify at-risk IOWs from the complete set of IOWs as classified through 24.3.2 IOW Determination.

24.3.3.2 At-Risk IOW Barrier Envelope Analysis

The purpose of a barrier envelope analysis is to assess well integrity for well control planning. It evaluates possible interwellbore communication flow path scenarios, identifies at-risk IOW barrier envelope(s) and corresponding barrier elements along the flow paths, and finally determines an Adjusted Maximum Pressure for each barrier element within each barrier envelope.

For the purposes of this interwellbore communication chapter only, the following definitions have been refined to interwellbore communication concerns at an offset well. Therefore, with respect to at-risk IOWs specifically:

- An **IOW barrier envelope** represents all the barrier elements on a possible interwellbore communication flow path that are dependent on each other for collectively preventing or controlling flow from a source. Therefore, a barrier envelope is a combination of barrier elements intended to prevent or control flow.

- An **IOW barrier element** refers to the individual equipment components or objects that together or collectively comprise a barrier envelope. For example: casing, casing hanger, packers, tubing hanger, tubing, wellhead valves are considered individual barrier elements. A barrier element as an object alone cannot prevent flow from one side to the other side of itself.

- The **Adjusted Maximum Pressure** at an at-risk IOW is determined by analyzing, for each barrier element within a barrier envelope, the original manufacture's equipment specification, age, and historic service.

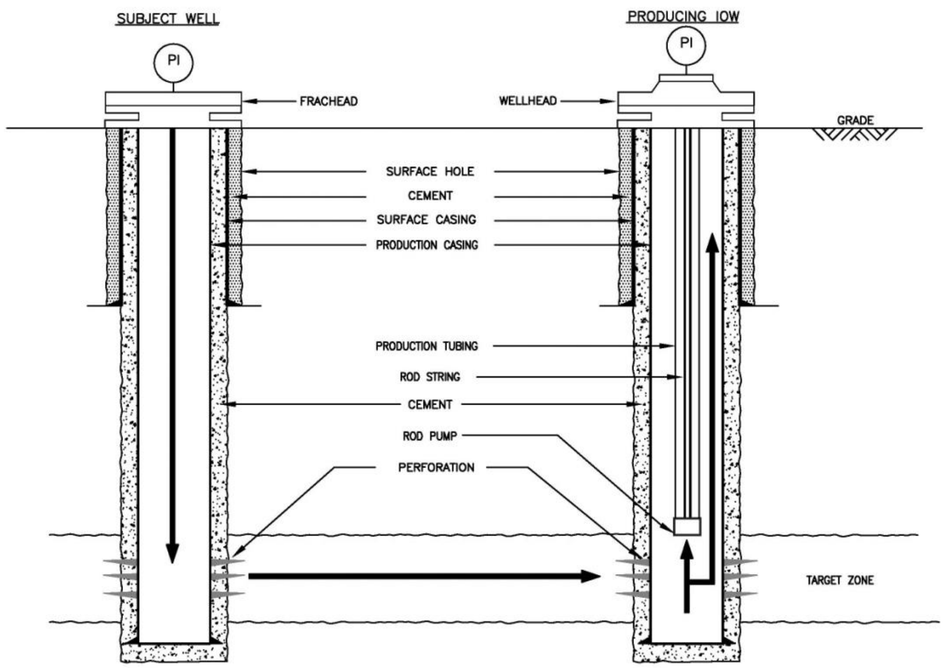
A **primary barrier envelope** is the first line of defense for preventing or controlling flow from a source. A primary barrier envelope may have a **secondary barrier envelope** in place that can prevent flow from a source in the event the primary barrier envelope fails or is compromised.

IRP The Subject Well Operator shall complete a barrier envelope analysis on each at-risk IOW.

A recommended barrier envelope analysis consists of the following four steps:

Step 1. Evaluate interwellbore communication flow path scenarios (see Figure 6: Target-to-target)
Flow paths at the at-risk IOW may occur through existing perforations, due to burst or collapsed casing, as a result of poor or lack of cement, or through open hole completion.

Figure 6. Example Target-to-Target Flow Path Illustration.



Step 2. Based on the flow path scenarios, identify primary and secondary barrier envelopes within each at-risk IOW. These may be illustrated on a barrier schematic. (See Appendix D for a sample barrier schematic and the Hazard Register for a blank barrier schematic template.)

Step 3. For each barrier envelope determine the Adjusted Maximum Pressures of each barrier element and identify which barrier element has the lowermost Adjusted Maximum Pressure.

Step 4. Assess groundwater protection at the at-risk IOW.
Note. If the barrier analysis reveals groundwater protection concerns at an at-risk IOW, then careful scrutiny of the at-risk IOW barrier system(s) is imperative. Prior to fracture stimulation, the Subject Well Operator may consider baseline water well testing.

24.3.3.3 IOW Proximity

The proximally closer an at-risk IOW is to a Subject Well fracture initiation point the greater the probability of interwellbore communication. The potential for a well control event at an at-risk IOW increases when it has a relatively low Adjusted Maximum Pressure with closer proximity to the Subject Well.

Quantitatively assessing the probability of interwellbore communication based on spatial distance alone is challenging, as there is no quantitative method for accurately predicting fracture propagation from the Subject Well. In addition to spatial distance, other factors can affect the probability of interwellbore communication, some of which are identified in Appendix C.

IRP For well control planning (24.3.4 IOW Well Control Plan), the Subject Well Operator should consider the proximity of the Subject Well to each at-risk IOW in relation to Adjusted Maximum Pressure(s) to minimize the risk of a well control event.

24.3.3.4 IOWs with Active Downhole Operations

It is imperative to pay specific attention to at-risk IOWs with active or pending downhole operations (e.g., drilling and well servicing). These at-risk IOWs may have an elevated well control risk that may require special planning (e.g., delaying fracture stimulation operations, or appropriate modification to fracture parameters at the Subject Well). Appropriate well control for at-risk IOWs with active downhole operations will require consultation and discussion between the Subject Well Operator and the IOW Operator (see 24.3.6 Operators' Consultation).

IRP **The Subject Well Operator shall ensure that at-risk IOW Operators with active downhole operations are aware of pending fracture stimulation operations at the Subject Well (see 24.3.6 Consultation).**

24.3.3.5 IRP Hazard Register

The Hazard Register is a tool to cross-reference the at-risk IOW barrier envelope analysis results against known hazard scenarios. Established Operators are encouraged to integrate the IRP 24 Hazard Register to augment existing processes and tools. Newer entrants may employ the Hazard Register as a basis for new process and tools.

IRP **The Operator shall employ the content of the IRP 24 Hazard Register or integrate IRP 24 known hazard scenarios into existing organizational risk assessment processes to identify additional risk assessment considerations.**

24.3.4 IOW Well Control Plan

IOW risk assessment is an essential first step to identify at-risk IOWs that require a well control plan. The well control plan is a response to the IOW risk assessment. It is of paramount importance to maintain well control in all at-risk IOWs by implementing a fully developed well control plan.

Special consideration of the condition of at-risk IOW abandoned wells and at-risk IOWs with active downhole operations is necessary to evaluate the restraints that may limit well control plan options.

Note. The Subject Well Operator is required to inform the Orphan Well Association or the AER of an at-risk IOW that has no legally responsible or financially able Operating Company (see 24.3.6 Operators' Consultation).

Consultation between operators is essential when an at-risk IOW is not operated by the Subject Well Operator. In this situation, a mutually agreed upon at-risk IOW well control plan needs to be collaboratively developed. This is particularly important for active or pending downhole operations. (See 24.3.6 Operators' Consultation.)

IRP Each at-risk IOW shall have a well control plan that reflects its risk assessment.

IRP The Subject Well Operator and the IOW Operator shall engage in a collaborative consultation process to develop a mutually-agreeable IOW Well Control Plan (see 24.3.6 Operators' Consultation).

This section discusses well control practices the Subject Well Operator may consider for at-risk IOWs. The Operators' consultation section addresses the iterative discussions expected between the Subject Well Operator and the IOW Operator to develop an appropriate well control plan.

24.3.4.1 IOW Well Control Practices

An at-risk IOW well control practice is a component of an IOW Well Control Plan. Practices are specifically selected and unique to each at-risk IOW based on the IOW Risk Assessment. They may include, but not be limited to, one or a combination of the following:

24.3.4.1.1 No Action Required

If the risk of a well control event is deemed low, then an IOW may not require any actions or may not need to be monitored during a Subject Well's fracture stimulation operation. Wells identified as minimal at-risk will have no action required (see 24.3.3.1 Determine At-risk IOWs)

24.3.4.1.2 Monitoring

This well control practice consists of observing at-risk IOW parameters (on flow paths in real-time) intended to trigger well control actions. At-risk IOW monitoring may occur either by remote device or onsite personnel. It is at the discretion of the Subject Well Operator and/or IOW Operator to develop the most appropriate method for the planned operation. It is important to have communication contingencies in place in the event of a monitoring communication failure.

24.3.4.1.3 Shut-in

This well control practice consists of shutting-in the at-risk IOW flow paths. It may be implemented on an at-risk IOW on which the risk assessment concluded that the adjusted maximum pressure is sufficient to retain well control.

24.3.4.1.4 Pressure Relieving System

This well control practice consists of a system of piping and fluid storage intended to contain fluid released from an at-risk IOW once a pre-determined pressure is reached on an at-risk IOW flow path.

Consider the following when designing a pressure relieving system:

- lowest adjusted maximum pressure on the flow path
- reservoir and/or fracture stimulation fluid type (e.g., gas or liquid, sweet or sour)
- maximum potential flow rate of fluid and/or gas from the at-risk IOW
- fluid volume
- IRP 4: Well Testing and Fluid Handling

24.3.4.1.5 Installation of Additional Barrier Elements

This well control practice consists of the installation of an additional barrier element to an existing barrier envelope to assure a greater level of well integrity at an at-risk IOW. An at-risk IOW's risk assessment response may require a temporary or permanent additional barrier element installed during fracture stimulation operations on the Subject Well. An additional element can include a downhole retrievable bridge plug or permanent downhole abandonment using an appropriate bridge plug with cement according to regulations.

24.3.5 Minimize Interwellbore Communication Hazards

With the IOW Well Control practices established, it is important to review these practices and contemplate if interwellbore communication risk has been minimized within the larger context of the Interwellbore Communication Hazard Management Process (ICHMP) and the Fracture Stimulation Hazard Management Process. Does the combination of determining IOWs within the FPZ, resulting at-risk IOWs, the IOW risk assessment and subsequent IOW well control practices produce a degree of confidence that interwellbore communication risk will be minimized? (This question aligns with the yellow diamond in the (ICHMP.)

If the Operator is confident that the planned controls and mitigations are within the Operator's risk tolerance and will minimize the risk of interwellbore communication causing a well control event at an IOW, then the Operator can begin the consultation with at-risk IOW Operators.

If upon reflection in the larger context, the Operator is uncertain that the planned controls and mitigations will minimize the risk of an interwellbore communication well control event, then the Operator needs to resolve why this may be the case. It may require the Operator revisit the interwellbore communication hazard management process by reviewing IOW FPZ determination (24.3.2.1), review the IOW risk assessment (24.3.3), and re-establishing IOW well control practices (24.3.4.1). It could also require the Operator modify timing on concurrent operations, or it may require the Operator revisit the fracture stimulation design (see 24.3.5.1 below).

24.3.5.1 Change Management

In situations where an at-risk IOW well control plan is deemed insufficient to minimize risk of a well control event, it may be necessary to make adjustments to the fracture stimulation design and subsequent program.

Change management at the Subject Well may include:

- adjusting fracture stimulation design,
- adjusting location of fracture initiation points in the case of a horizontal well,
- skipping and/or blank-off fracture stimulation stages in the case of a horizontal well, and/or
- adjusting surface location and/or wellbore trajectory.

24.3.6 Operators' Consultation

Discussion and consultation between the Subject Well Operator and an Identified Offset Well (IOW) Operator are inevitable and necessary. Operators are expected to engage in discussion and continue dialogue through collaborative consultation in an effort to achieve a mutually-agreed upon well control plan for an at-risk IOW (see 24.3.4 IOW Well Control Plan).

Collaborative consultation implies consensus decision-making that seeks the consent of all participants with the ultimate goal of avoiding a well control event. The nature of consensus decision-making involves discussion, debate, and iteration. The number of iterations is likely to increase with the complexity of the operation and the condition of the at-risk IOW. Subject Well Operators are expected to have a strong understanding of the complexity of the project to allow for appropriate lead time and account for the potential for multiple iterations during the consultation process.

The efficiency of a process lies in the clarity of each party's responsibilities:

IRP To support the effectiveness of consultation between the Subject Well Operator and an Identified Offset Well Operator[5], the Subject Well Operator shall at a minimum be responsible for the following actions as part of the consultation process:

- **Initiate a formal consultation request prior to the planned fracture stimulation operation (suggested 30 days)[6], with appropriate lead time for the IOW Operator to respond (suggested within 15 days of consultation request):**
    - **to inform the IOW Operator of an IOW that may be at-risk from the Subject Well Operator's pending fracture stimulation, and**
    - **to engage in consultation and dialogue to collaboratively develop and mutually agree to an IOW well control plan for the period when the Subject Well will receive fracture stimulation.**
- **Re-initiate a formal consultation request if there is no response within a reasonable amount of time.**

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[5] In a situation where an at-risk IOW has no legally responsible or financially able Operating Company, the Orphan Well Association or the AER is considered the IOW Operator (see Glossary, IOW Operator).

[6] This suggested 30 days is a guideline intended to provide suitable lead time for the initial communication to reach the appropriate individual at the IOW Operator, and allow time for the IOW Operator to reply. It is expected that there are Operators who have established and favourable existing working relationships where 30 days lead time may not be necessary.

- **Provide the IOW Operator a minimum amount of data about the planned fracture stimulation operations including:**
    - **Subject Well license, IOW license and Unique Well Identifier (UWI);**
    - **zone and/or TVD of the fracture stimulation taking place in the Subject Well;**
    - **map of the FPZ (see 24.3.2.2 Fracture Planning Zone Well Identification);**
    - **distance from the Subject Well to the IOW; and**
    - **expected date of the fracture stimulation.**
- **Establish communication contacts at the field level between the Operators, for pre-, during and post-fracture stimulation notification.**
- **Engage in collaborative consultation to develop a mutually-agreeable IOW Well Control Plan.**
- **Finalize documentation and appropriate field level notifications of the confirmed IOW Well Control Plan.**

It is recommended the Subject Well Operator maintain records of communications with the IOW Operator regarding the consultation process, and including agreed confirmation of the final IOW Well Control Plan.

IRP To support the effectiveness of consultation between the Subject Well Operator and an Identified Offset Well Operator, the IOW Operator shall at a minimum be responsible for the following actions as part of the consultation process:

- **Develop an internal process to review and respond to the Subject Well Operator.**
- **Establish a well-publicized and moderated corporate notification process (e.g., phone number and/or email address).**
- **Assign a competent individual with knowledge of the IOW(s) in question.**
- **Acknowledge suggested within 15 days upon the receipt of a Subject Well Operator consultation request.**
- **Provide all publically available wellbore data (e.g., survey, tubulars, cement tops, stimulations)**

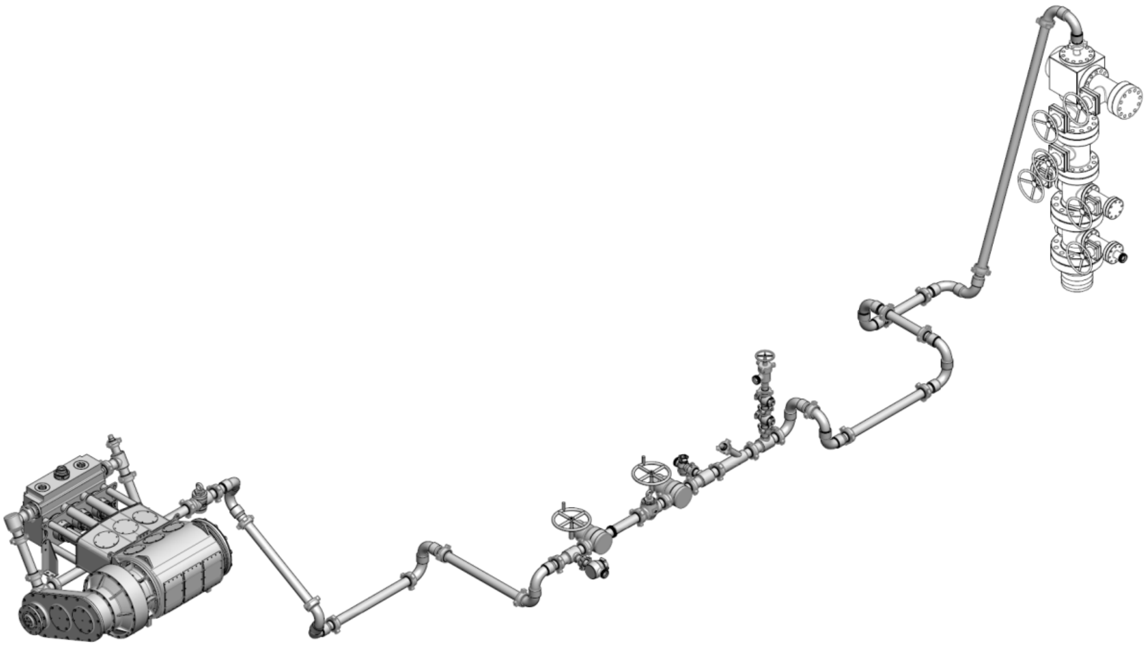
- **Disclose any impending operations at the offset well that may be influenced by the proposed fracture stimulation.**
- **Engage in collaborative consultation with the goal of developing a mutually-agreeable IOW Well Control Plan.**
- **Finalize documentation and appropriate field level notifications of the confirmed IOW Well Control Plan.**
- **In the event of an unexpected pressure communication approaching the IOW's AMP notify the Subject Well Operator's field contact.**

It is recommended the IOW Operator maintain records of communications with the Subject Well Operator regarding the consultation process, and including agreed confirmation of the final IOW Well Control Plan.

24.4 Surface Operations

The Surface Operations chapter initiates assessment at the fracture iron where Subject Well Integrity Assessment ends.(see the grey shaded area in Figure 7) This chapter determines surface areas, identifies hazards and reviews considerations for hazard management planning and wellsite execution.

Figure 7. Surface Operations includes all equipment and activities above ground with the exception of the well head equipment (not shaded below) which is covered in the Subject Well Integrity chapter.



Fracture stimulation operations are complex operations. Activities associated with multi-well leases may result in increased activity and congestion surrounding a well under erosive, high pressure. Thorough planning before fracture operations begin can mitigate or control identified and industry known hazards (IRP 24 Hazard Register). It is the Subject Well Operator's responsibility to review surface operations in the planning stages to minimize the probability of surface hazards.

IRP **The Subject Well Operator shall minimize surface hazards (to workers, public and environment) resulting from fracture stimulation operations at the Subject Well.**

REG If an incident occurs at the wellsite as a result of fracture stimulation operations then the Subject Well Operator's Emergency Response Plan (ERP) must be invoked in accordance with *D071: Emergency Preparedness and Response Requirements for the Petroleum Industry* or relevant jurisdictional regulations.

Common options to minimize surface hazards include, but are not limited to:

1. Conduct appropriate Surface Operations Hazard Management Planning by consulting and employing the *IRP 24 Surface Hazard Management Process* (see Figure 8).

2. Adjust the Fracture Stimulation Program.

3. Modify timing to minimize concurrent operations.

24.4.1 Surface Hazard Management Process

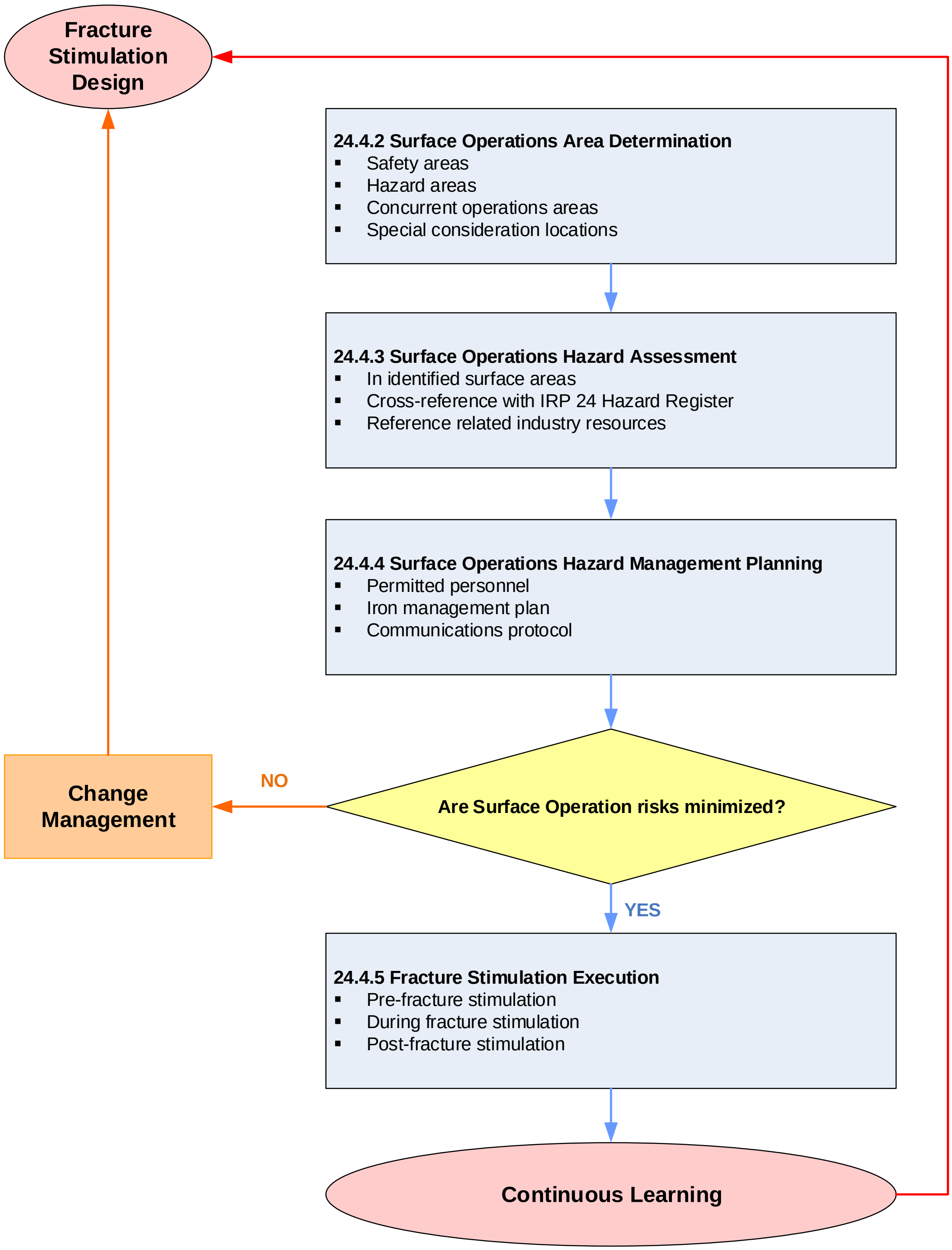
The Surface Hazard Management Process (SHMP) is part of the larger Fracture Stimulation Hazard Management Process. The SHMP portion of the process determines surface hazards of greatest concern on the lease and/or resulting from related activities necessary to support the fracture stimulation operation.

The SHMP provides a set of recommended practices for both the Subject Well Operator and Service Providers to conduct appropriate surface operations hazard management planning (24.4.4) based on a surface operations hazard assessment (24.4.3).

Note. The SHMP is not intended to replace existing organizational risk assessment processes and associated risk analysis tools or registers, nor is it intended to provide a complete risk analysis tool for organizations. Established Operators may use IRP 24's SHMP and the IRP 24 Hazard Register (24.4.3.2) to augment existing processes and tools. Newer entrants may use the SHMP and Hazard Register as a basis for new processes and tools. Regardless how an organization chooses to implement the SHMP and Hazard Register, the IRP 24 Committee supports and recommends that both be implemented for all fracture stimulation operations.

Figure 8 illustrates the SHMP in relation to the sections of this document. Process boxes (in blue) are aligned with corresponding section headers in this chapter. The bullet points in each process box summarize key elements in the related section. A decision point box is noted with a yellow diamond and change management is in an orange box. The pink ellipse illustrates how the SMHP links back to the larger Fracture Stimulation Hazard Management Process detailed in Chapter 1.

Figure 8. Surface hazard management process.



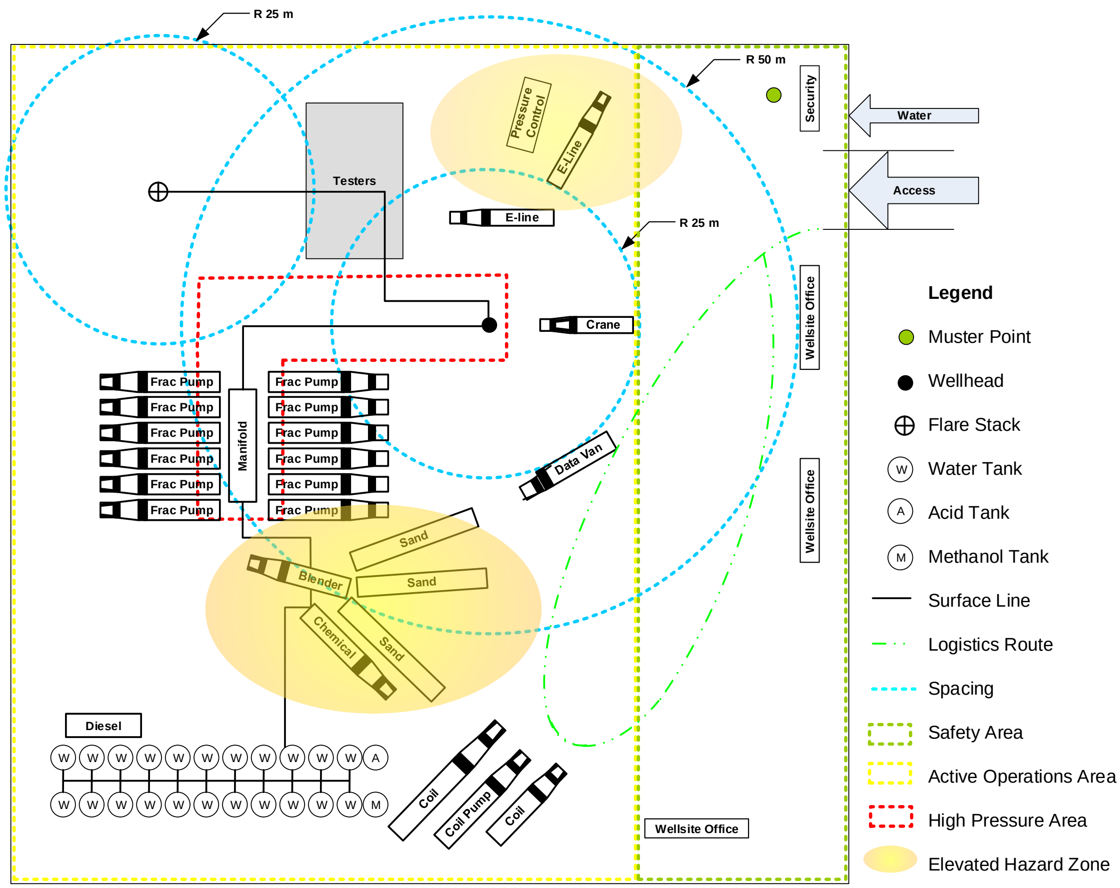
24.4.2 Surface Operations Area Determination

The outer boundary of the lease defines an area of influence surrounding the Subject Well within which surface hazards are identified and managed. On the lease, surface hazard assessment needs to consider safety areas, hazard areas (that include Active Operations Areas, High Pressure Areas, Elevated Hazard Zones), and concurrent operations. Beyond the lease boundaries, there may be special consideration locations that require surface hazard assessment.

IRP The Subject Well Operator shall determine relevant safety areas, hazard areas (that include Active Operations Areas, High Pressure Area and Elevated Hazard Zones), concurrent operations and special consideration locations for the fracture stimulation operation.

To promote effective communication and ensure accessibility to all field workers, it is suggested the Subject Well Operator prepare and post a lease map onsite denoting the safety and hazard areas, indicating the level of hazard (Active Operation, High Pressure, Elevated Hazard Zone) and illustrating proximity to fracture stimulation operations. Examples are provided in Figures 9 through 16 below.

Figure 9. Safety Area and Hazard Area

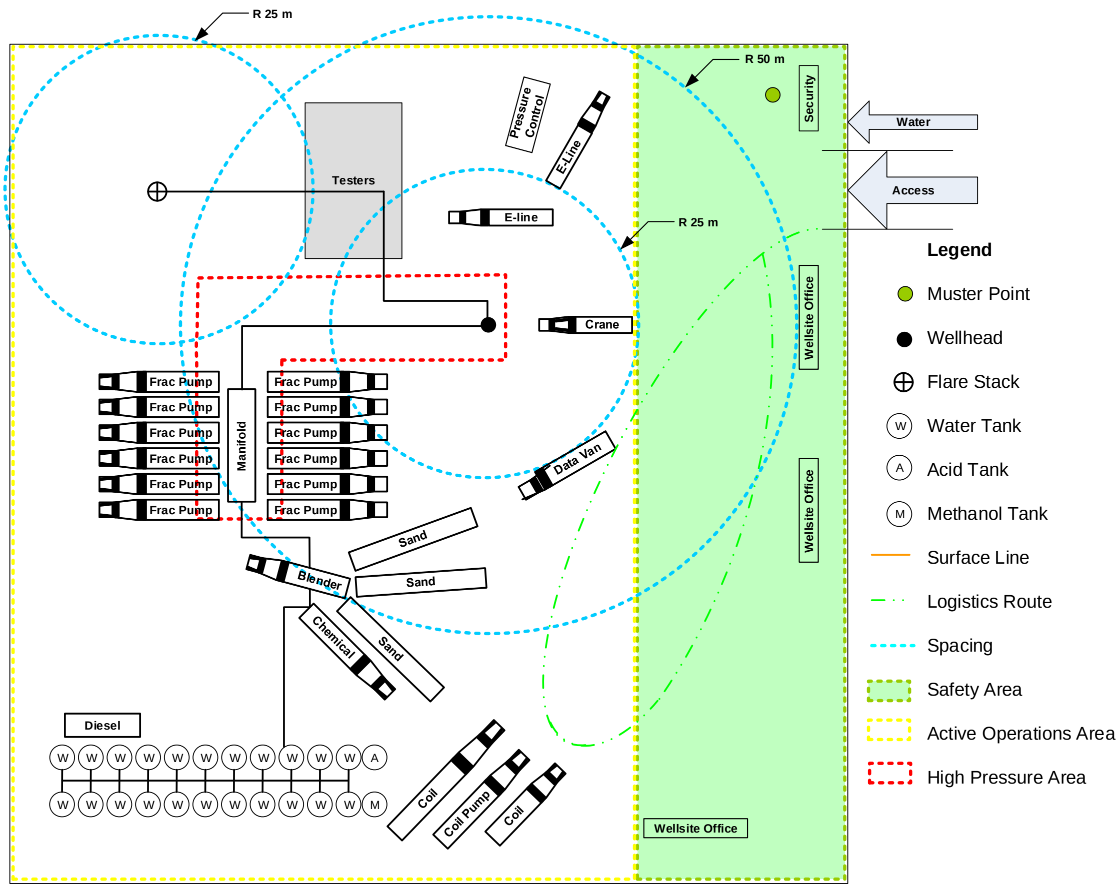


24.4.2.1 Safety Areas

The Safety Area is a designated section, or sections, of the lease where workers can muster, egress or locate first aid. These locations may be used for safety meetings and job preparations (see Figure 10).

IRP The Subject Well Operator in consultation with the Service Provider(s) shall determine the location of the Safety Area on the lease.

Figure 10. Safety Area.



24.4.2.2 Hazard Areas

Fracture stimulation operations create unique safety challenges on the lease. Onsite congestion coupled with high pressure increase hazards in specific locations. There are three types of on-lease hazard areas: the Active Operations Areas, High Pressure Area, and Elevated Hazard Zones.

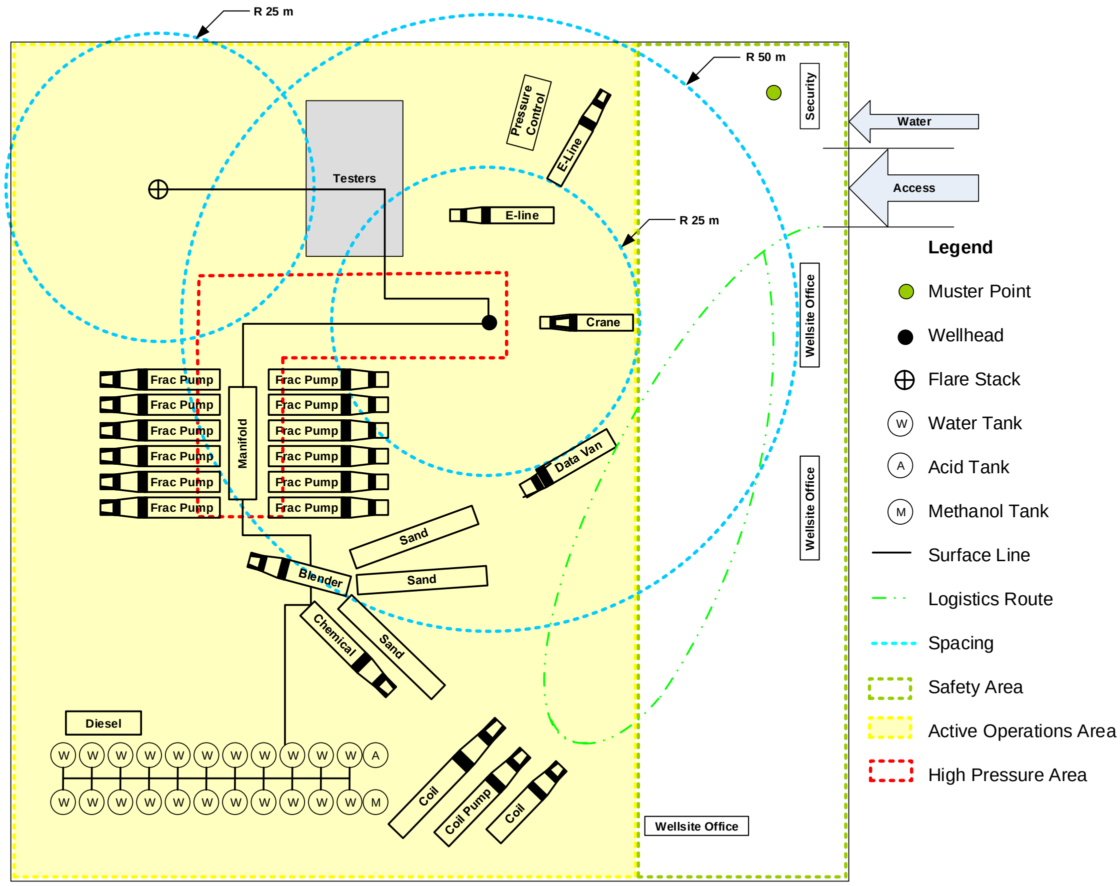
The location of the hazard areas shifts as the operation progresses. It is important that amendments to the hazard areas be communicated to personnel when tasks or operations change (see 24.4.6.4 Operational Change).

Active Operations Area

The Active Operations Area is a designated portion of the lease that contains the fracturing operations (see Figure 11). It includes the High Pressure Area (see Figure 12) and zones containing elevated hazards (see Figure 13). Personnel in the Active Operations Area may be limited to essential personnel only.

IRP The Subject Well Operator, in consultation with the Service Provider(s), shall determine the portion of the lease designated as the Active Operations Area.

Figure 11. Active Operations Area



High Pressure Area

The High Pressure Area envelopes all the high-pressure iron connecting the fracture pump fluid-ends to the wellhead. Since it is a restricted area, its location and boundary are to be determined in consultation between the Operator and the Service Provider(s). It is imperative that the Operator and Service Provider work together to ensure that all reasonable efforts are made to limit exposure or access to the High Pressure Area (see 24.4.4 Surface Operations Hazard Management Planning). Designated personnel may need to enter the High Pressure Area only under special circumstances. There may be more than one High Pressure Area on the lease at any one time. The High Pressure Area typically shifts as the operations progress (see Figure 12).

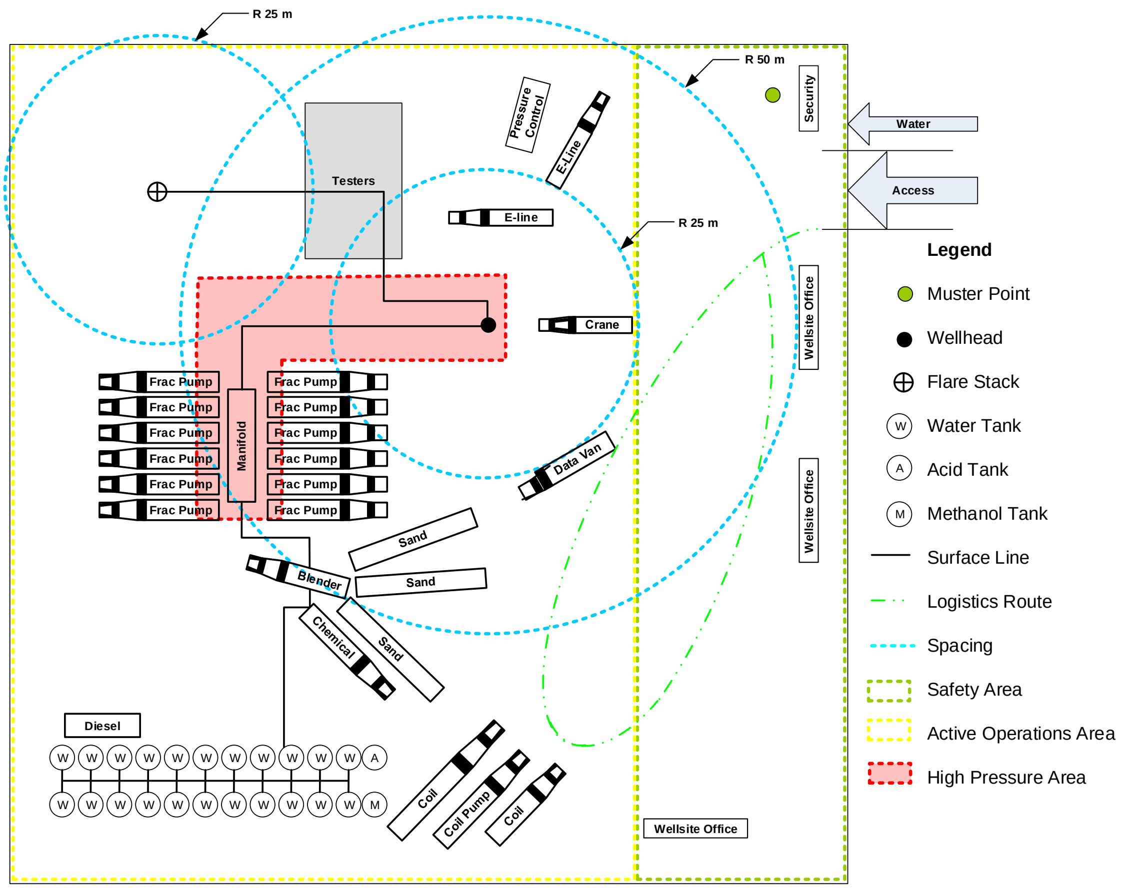
IRP The Subject Well Operator in consultation with the Service Provider(s) shall determine the location and boundary of the High Pressure Area and reassess appropriately as the fracture operation progresses.

IRP The boundary of the high pressure area shall be a minimum of 3 m from the high pressure lines. Beyond the 3 m minimum, it is expected the Operator and Service Provider(s) assess the following factors to expand the boundary of the High Pressure Area:

- **sweep radius of the iron (chiksan to chiksan)**
- **equipment restraining the sweep radius of the iron**
- **maximum anticipated surface treating pressure**
- **presence of energized fluids**

Since this is a restricted area that presents increased risk to personnel, a visual barrier, a strong communication protocol, and/or some clear means of denoting the High Pressure Area, is encouraged.

Figure 12. High Pressure Area



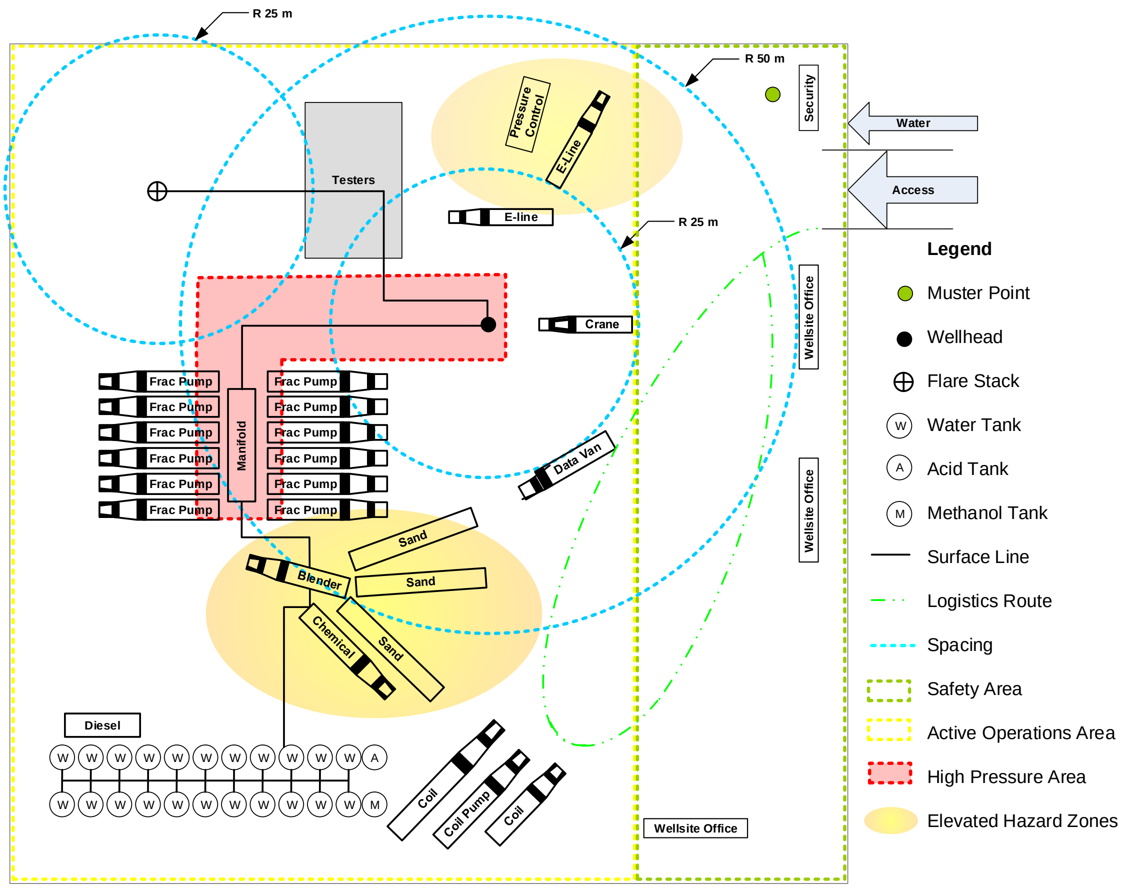
Elevated Hazard Zones

As surface operations initiate and progress within the Active Operations Area there are fracture support operations that present elevated hazards within the Active Operations Area. These Elevated Hazard Zones require prudent attention from personnel. They include activities such as silica exposure, wireline operations, fracture fluid transfer, low pressure equipment, or fuelling while pumping (see Figure 13).

IRP The Subject Well Operator in consultation with the Service Provider(s) shall identify elevated hazard zones and re-assess appropriately as the fracture operation progresses.

It is expected that the Wellsite Supervisor discuss Elevated Hazard Zones of concern at a safety meeting to alert permitted personnel (see 24.4.6 Fracture Stimulation Execution). A visual barrier may be used to distinguish Elevated Hazard Zones in the Active Operations Area as illustrated in Figure 13.

Figure 13. Elevated hazards in the Active Operations Area



24.4.2.3 Concurrent Operations

Concurrent operations refer to any other operation not associated directly with the fracture operation, yet occurring on the same lease or pad. These concurrent operations increase the probability for surface incidents on the lease shared by the fracture stimulation operations and thereby increase risk to all stages of a fracture stimulation operation (pre, during, post). For effective hazard management planning, it is important to determine the location of concurrent operations and be aware of proximity to the Subject Well.

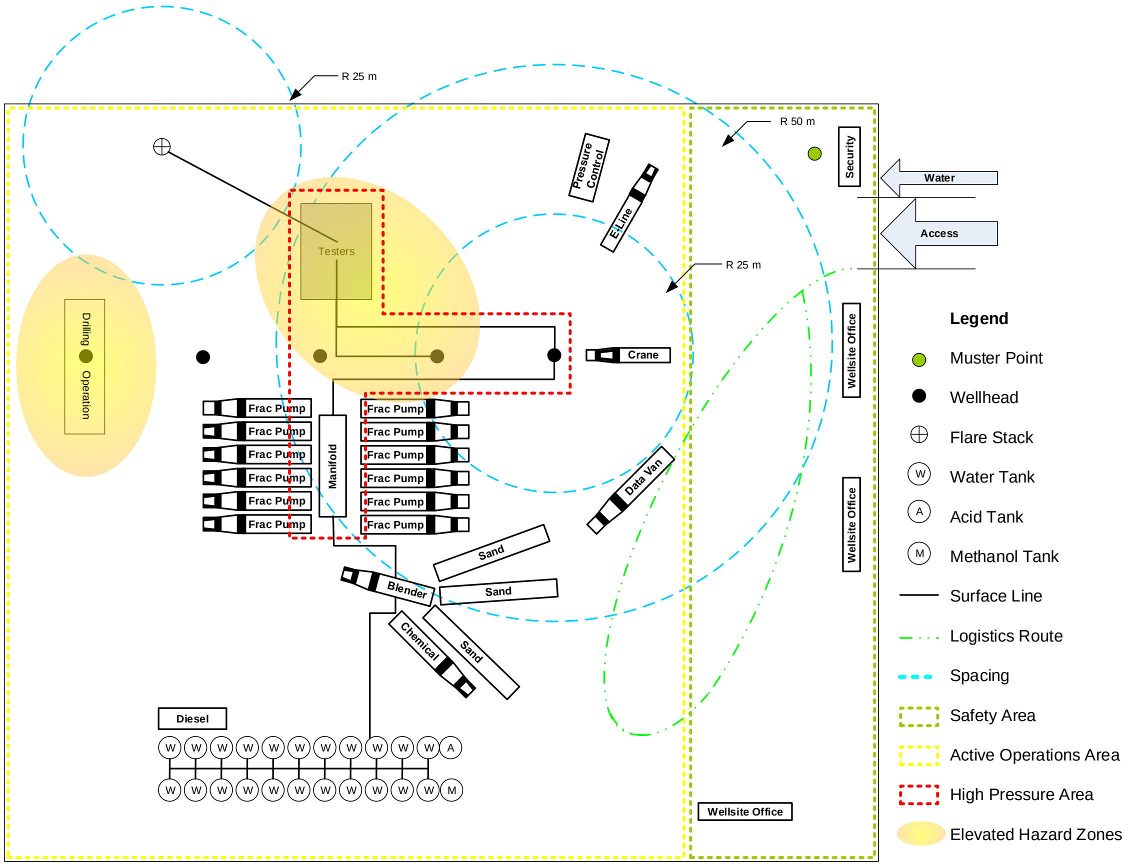
Concurrent operations on a lease may include, but not be limited to:

- flowback (as illustrated in Figure 14),
- wireline operations in progress on an adjacent wellbore,
- drilling while fracturing (see also 24.3.3.4 IOWs with Active Downhole Operations for downhole considerations),
- other completions operations (e.g., coiled tubing), or
- facility installation.

IRP The Subject Well Operator in consultation with the Service Provider(s) involved shall determine the location of concurrent operations within the Hazard Areas and throughout the duration of the fracture stimulation operation.

There are some concurrent operations that require an expansion of a hazard area. For example in Figure 14 below the High Pressure Area has been enlarged to include flowback equipment. There are also some concurrent operations that may be considered Elevated Hazard Zones as illustrated by the orange ellipses in Figure 14. The flowback equipment is encircled with the orange ellipse to draw attention to areas beyond the High Pressure Area that workers should be aware are considered concurrent operations. Additionally, concurrent operations such as an ongoing drilling operation on the same pad need to be noted and hazards assessed and controlled.

Figure 14. Concurrent Operations



24.4.2.4 Special Consideration Locations

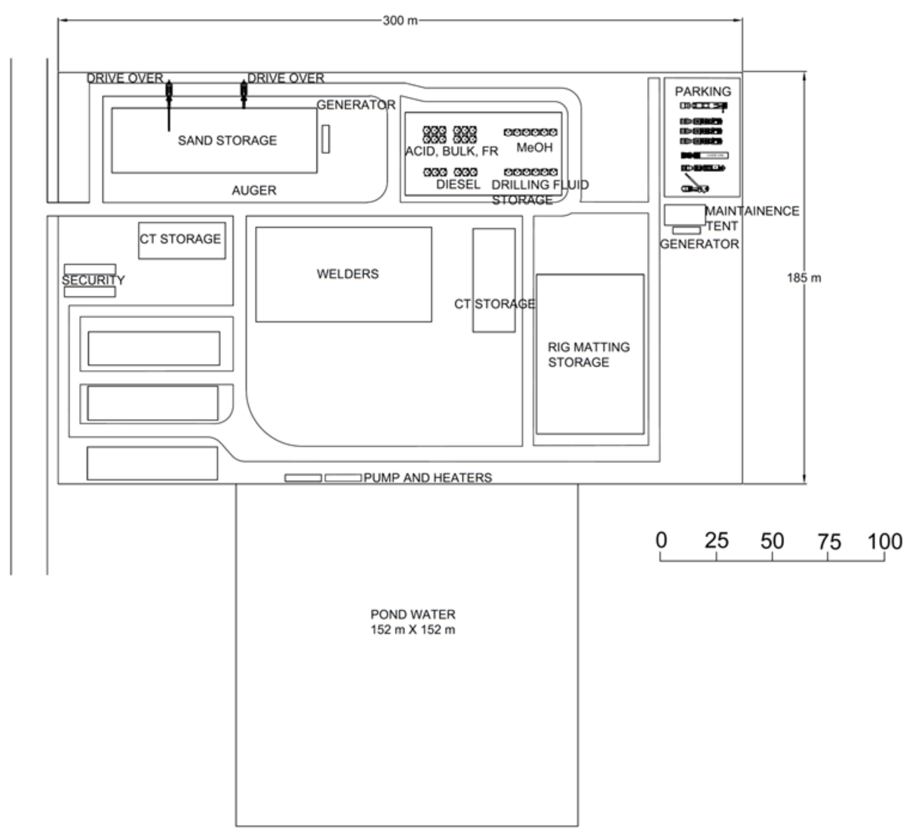
Fracture stimulation operations may require off-site transport, maintenance, storage of equipment, and materials. Special consideration is necessary for off-lease locations that may be impacted throughout the entirety of the fracture stimulation operation. See Figure 15 for a sample illustration of a special consideration location.

Special considerations relevant to off-lease surface risk may include, but not be limited to:

- any extension of fracture stimulation operations off-lease
- proximity to public and residential locations
- road usage
- offset wells included in the IOW Risk Assessment
- environmentally sensitive areas and wildlife
- other existing infrastructure (e.g., power lines, pipe lines)

IRP The Subject Well Operator in consultation with the parties involved shall determine the location of special consideration locations.

Figure 15. Special Considerations Locations



24.4.3 Surface Operation Hazard Assessment

The surface hazard area of influence is defined by determining surface safety areas, hazard areas, anticipated concurrent operations, and special consideration locations (see 24.4.2). The combination of these four denotes the regions for surface hazard assessment. Thorough surface hazard assessment sets the framework for Surface Operations Hazard Management Planning (see 24.4.4).

IRP The Subject Well Operator shall identify hazards in the following pre-determined areas:

- **safety area(s),**
- **hazard areas,**
- **concurrent operations areas, and**
- **special consideration locations.**

Surface operations hazard assessment is organized into stages:

1. Hazard identification
2. Cross-reference with the IRP 24 Hazard Register
3. Cross-reference with related IRPs.

24.4.3.1 Hazard Identification

Along with the Hazard Register there are several topics significant specifically to fracture stimulation operations that require explicit attention. It is important to identify and assess relevant hazards in following areas:

Safety areas

Hazards in the safety areas can be easily overlooked. Particularly in the event of a surface incident, the safety area needs to be conducive to easy entry and exit on foot or vehicle. Pay special attention to uneven or slippery ground and obstacles that block entry or exit.

Hazard areas
(High Pressure Area, Active Operations Area, Elevated Hazard Zones)

Given the nature of fracture stimulation treatment and working conditions, surface equipment, the pipe body, and connections are under stress which create potential hazards such as:

- erosion,
- over-pressuring,
- chemical degradation, and/or
- stress fatigue.

Mitigation and control options regarding these specific surface hazards are presented in the Hazard Register. It is important Operators review for these particular hazards and account for the nuances of the site's fracture stimulation program when developing control measures.

Concurrent operations

The severity of a surface incident at a concurrent operation and its proximity to the Subject Well will increase the probability and risk of a surface incident at the fracturing operation. Surface hazards resulting from concurrent operations may include:

- an unexpected kick while drilling,
- a perforating detonation before deploying in the wellbore, or
- an uncontrolled flowback of wellbore fluids at an adjacent well.

Interwellbore communication at an offset well may result in surface hazards. Onsite downhole concurrent operations that impact the Subject Well is detailed in the interwellbore communication chapter, specifically 24.3.3 IOW Risk Assessment. These onsite offset wells are considered IOWs (Identified Offset Wells) and included in the IOW Risk Assessment.

Special consideration locations

It is important to assess relevant hazards at each special consideration location. Potential hazard scenarios are listed in the Hazard Register. Operators are encouraged to pay particular attention to concerns regarding:

- containment and handling of chemical, flowback fluids, fuel, proppant, equipment; along with,
- site supervision and security issues.

24.4.3.2 IRP 24 Hazard Register

The surface operations hazard scenarios in the IRP 24 Hazard Register offer industry-known surface hazards possibly not familiar to all Operators. It provides Operators a way to be predictive about the potential for new hazards before an incident occurs. Operators are encouraged to cross-reference hazards identified in the surface areas with the IRP 24 Hazard Register.

IRP The Subject Well Operator shall employ the IRP 24 Hazard Register to hazard assess determined safety areas, hazard areas, concurrent operations and special consideration locations.

24.4.3.3 Reference Related Resources

A review of relevant IRPs and guidelines may provide additional guidance. Examples may include the following:

- IRP 4: Well Testing and Fluid Handling
- IRP 5: Minimum Wellhead Requirements
- IRP 7: Standards for Wellsite Supervision of Drilling, Completion and Workovers
- IRP 8: Pumping of Flammable Fluids
- IRP 13: Slickline Operations
- IRP 20: Wellsite Design Spacing Recommendations
- IRP 21: Coiled Tubing Operations

24.4.4 Surface Operations Hazard Management Planning

Working through the determined surface areas to assess surface hazards highlights the association between surface hazard severity and the hazard area proximity to the fracture operation. Surface operations hazard management planning is intended to determine the control measures for surface hazards identified in the safety area, hazard areas, concurrent operations areas and special considerations locations with attention to hazard severity and proximity to the fracture operation.

IRP The Subject Well Operator shall conduct surface operations hazard management planning that includes control measures for hazards identified in surface operations areas (safety area, hazard areas, concurrent operations areas and special consideration locations).

24.4.4.1 Determine Permitted Personnel

Restricting certain areas to some personnel is a key control measure to mitigate hazards during a fracture operation. It is important to review each surface area throughout the fracture operation for modifications to personnel restrictions as the operation progresses.

The High Pressure Area contains the highest risk on site. It is imperative that the Operator and Service Provider work together to ensure that all reasonable efforts are made to limit exposure or access to the High Pressure Area.

IRP The Subject Well Operator shall conduct hazard management planning to determine permitted personnel, duration of exposure, permitted tasks, and tools that address hazards in the following:

- **safety areas,**
- **hazard areas,**
- **concurrent operations areas, and**
- **special consideration locations.**

24.4.4.2 Iron Management

Given the nature of fracture stimulation treatment and working conditions, surface equipment, the pipe body, and connections are under stress which can influence the potential for erosion, over-pressuring, chemical degradation, and stress fatigue.

IRP The Subject Well Operator shall ensure the Service Provider has an iron management plan.

A Subject Well Operator may expect a Service Provider's iron management plan considers at a minimum the following:

- documented inspections and validation
- identification and tracking system
- manufacturer's operational specifications
- erosion
- chemical / environmental degradation
- temperature
- stress fatigue

Restraint requirements differ among provinces. Alberta and BC regulations can be accessed:

- Alberta's OHS Part 12 *General Safety Precautions*, Section 188 Restraining hoses and piping http://work.alberta.ca/documents/WHS-LEG_ohsc_p12.pdf
- Saskatchewan's OHS, *The Occupational Health and Safety Regulations*, 1996, Pressurized hoses 131, pg. 77. http://www.qp.gov.sk.ca/documents/English/Regulations/Regulations/O1-1R1.pdf
- Worksafe BC *Guidelines Part 23*, G23.69(3) Restraint of piping systems https://www2.worksafebc.com/publications/ohsregulation/GuidelinePart23.asp

REG The Subject Well Operator must ensure iron securement adheres to jurisdictional regulations.

24.4.4.3 Communications Protocol

Concurrent and supporting operations in close proximity to the Subject Well increase the probability of surface hazards. Regular and effective communication among all parties involved is essential. A communication protocol may include onsite operations staff, such as third party suppliers who are on site for extended periods (e.g., fire suppression, fuel, chemical and medical personnel).

IRP The Subject Well Operator shall establish a communication protocol in consultation with services active in surface operations areas.

24.4.5 Minimize Surface Hazards

Once hazard management planning is complete, it is important to review the plan and contemplate if surface operation risk has been minimized within the larger context of the Surface Operations Hazard Management Process and the Fracture Stimulation Hazard Management Process. Does the combination of the hazards identified within the pre-determined surface areas produce a degree of confidence that surface operation risk has been minimized by the set of controls and mitigations? (This question aligns with the yellow diamond in the (SOHMP.)

If the Operator is confident that the planned controls and mitigations will minimize surface operation risk within the Operator's risk tolerance then the fracture operation can move to execution.

If upon reflection in the larger context, the Operator is uncertain that the planned controls and mitigations will minimize surface operations risk within the Operator's risk tolerance, then the Operator needs to resolve why this may be the case. It may require the Operator review and revise surface operations hazard management planning by revisiting activities as part of surface operations area determination (24.4.2) and surface operation hazard assessment (24.4.3). It may require the Operator modify timing on concurrent operations, or it may require the Operator revisit the fracture stimulation program.

Only once the Operator has established a degree of confidence that surface operation risk has been controlled and mitigated within the Operator's risk tolerance may the Operator move to fracture stimulation execution.

24.4.6 Fracture Stimulation Execution

Once the fracture stimulation operation is underway the success of execution is highly reliant on effective communications with personnel. Special attention is required regarding the High Pressure Area. The conditions that impact the degree of risk in the High Pressure Area change as the operation progresses. It is important the Subject Well Operator and the Service Provider(s) be in communication to ensure it is understood when the High Pressure Area is active.

IRP **The Subject Well Operator / Wellsite Supervisor in consultation with the Service Provider(s) shall communicate the following for each determined surface operations area (see 24.4.2):**

- **hazards and control measures**
- **elevated hazard zones within any of the surface operations areas**
- **permitted access personnel**
- **duration of exposure**
- **permitted tasks and tools**

Surface hazard management planning may be categorized chronologically: pre-fracture, during and post-fracture stimulation operations.

REG **The Subject Well Operator must confirm casing integrity pre-, during and post fracture stimulation operations in accordance with *Directive 083: Hydraulic Fracturing - Subsurface Integrity*, and relevant jurisdictional regulations.**

IRP The Subject Well Operator should ensure the AMP is not exceeded pre-, during or post fracture stimulation operations.
Note. Ensure pressure is relieved after the pressure test is completed.

24.4.6.1 Pre-Fracture Stimulation

Pre-fracture stimulation refers to all on-lease activities in relation to the fracture stimulation that occurs before pressurizing the high-pressure iron. Fracture stimulation operations may experience simultaneous events that need to be communicated to personnel before fracture operations begin.

Pre-fracture stimulation surface hazards may not be obvious to onsite personal; for example, the presence of silica dust during sand transfers to onsite storage. Personnel need to be responsible for their awareness of surface hazards.

Before pressurizing the high-pressure iron, it is imperative all personnel are aware that:

- Additional obstacles on the ground, like treating iron, are tripping hazards.
- Treating iron is rigged-in to allow for normal movement (jacking) while minimizing wear points during pumping operations.
- Treating iron is restrained according to local jurisdictional requirements (see 24.4.4.2 Iron Management)
- Proppant and product transport can be continuous which causes a large volume of vehicle traffic. This congestion leaves poor sight lines for personnel on foot and in vehicles.
- There are hazardous chemicals and materials as part of any fracture stimulation operation (e.g., silica dust, hydrochloric acid, hydrocarbons and other stimulation chemicals). It is important to ensure there are plans to minimize exposure.

The Subject Wellsite Supervisor plays a significant role in both communications and operations. This individual needs to have working knowledge of the subject well integrity concerns and any IOW concerns.

IRP Prior to initiation of fracturing operations, the Subject Wellsite Supervisor shall ensure that the Subject Well Controls have been executed (see 24.2.4 Subject Well Control).

IRP Prior to initiation of fracturing operations, the Subject Wellsite Supervisor should ensure that the IOW Operator has executed the mutually agreed well control plan (see 24.3.4 IOW Well Control Plan).

The Subject Wellsite Operator may consider collecting IOW pressure data in advance of the fracture stimulation operation to create baseline data.

The Subject Wellsite Supervisor may expect the following additional responsibilities unique to fracture stimulation:

- Review and confirm the accuracy of data and information supplied in the IOW Well Control Plan.
- Ensure contingencies are in place in the event of an IOW monitoring communication failure.
- Consider a drive-around recce of the FPZ to determine if other operations are planned to occur at the time of the fracture stimulation.

- Effectively communicate with IOW active downhole operations Wellsite Supervisor prior to the Subject Well fracture stimulation operations.
- Ensure monitoring described in the IOW Well Control Plan is fully operational.
- Ensure all IOW field notifications have been completed (see 24.3.6 Operators' Consultation).
- Ensure the implementation of the IOW Well Control Plan, as mutually agreed upon between the Subject Well Operator and the IOW Operator.

24.4.6.2 During-Fracture Stimulation

It is imperative that the Subject Wellsite Supervisor has functional knowledge of operations surrounding and at the Subject Well including:

- surface areas
- surface hazards and control measures
- fracture stimulation program and related subject well control measures
- at-risk IOWs in the FPZ and the supporting IOW Well Control Plan
- other operations associated with fracture operations (e.g., plug-and-perf on an offset well to the well being fractured) and the related IOW Well control plan

REG The Subject Well Operator must maintain a copy of the IOW Well Control Plan at the Subject Wellsite in accordance with *Directive 083: Hydraulic Fracturing – Subsurface Integrity*.

It is equally critical that the Subject Wellsite Supervisor is capable of efficiently and appropriately assessing multiple streams of data that may require the initiation of IOW Well Control. The Subject Wellsite Supervisor may expect the following additional responsibilities unique to fracture stimulation:

- Effectively communicate with IOW active downhole operations Wellsite Supervisor during the Subject Well fracture stimulation operations.
- If a well control event occurs, subject well integrity fails or communication to an IOW occurs, the Wellsite Supervisor is required to initiate notification as per Directive 083: Hydraulic Fracturing - Subsurface Integrity or in accordance with relevant jurisdictional regulations.

- Take appropriate actions on the Subject Well to reduce the hazards when approaching the Subject Well's or an IOW's adjusted maximum pressure (i.e., go to flush, stop pumping, relieve pressure, etc.).

Once the fracture stimulation is underway, personnel need to be aware of any shift in hazards and related controls which may include:

- Subject Wellsite Supervisor communicating to all personnel the location of the Safety Areas and the controls in place to restrict access.
- A communications protocol outlining communication with various Service Providers' onsite personnel including those involved in concurrent operations, and any communications plans for IOWs (see 24.3.6 Operators' Consultation).

IRP The Subject Well Operator should have a communication protocol that uses a "triple handshake" method when any valve is being opened or closed along the fracturing fluid flow path**.**
Note. The triple handshake method should include the Wellsite Supervisor, the Fracture Supervisor, and all other Service Providers impacted by the fracture fluid flow path.

- Personnel identified to constantly monitor the treating iron and Subject Well surface equipment for:
    - to ensure the treating iron can move freely (jacking) while paying attention to potential wear points.
      Note. Iron that is bound, will cause stress cracking
    - leaks (small leaks can turn into big holes quickly)
    - pressures are not to exceed the AMP of the wellhead or the OEM pressure rating of the surface equipment while being in accordance with jurisdictional requirements.
      Note. Alberta OHS regulations state that you must pressure test the lines between the frac pump and wellhead at 10% above anticipated service pressure and the test cannot exceed the OEM rated working pressure of the equipment.
    - rates are not to exceed OEM suggested maximum linear velocity (may differ for viscosified and non-viscosified fluids)

24.4.6.3 Post-Fracture Stimulation

Post-fracture stimulation refers to all operations that occur after the treatment iron has been de-pressurized. Post-fracture stimulation operations experience many of the same surface risks as pre-fracture stimulation operations. However, flowback risks are an additional concern and discussed in the hazard register.

Post-fracture stimulation activities include:

- Evacuate fluid from all lines
- Concurrent operation notification (pad drilling, perforating, adjacent wellbores)
- At-risk IOW Operator notification

24.4.6.4 Operational Change

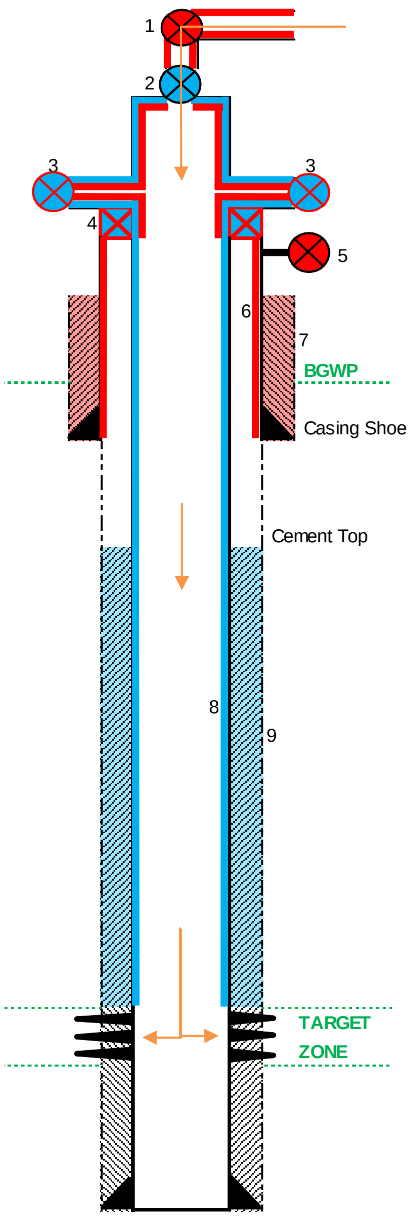
Once a fracture stimulation operation has commenced, operational plans, can and often do, change. It is imperative to re-evaluate surface hazards when operational plans change and regularly review the surface areas for elevated hazard zones and concurrent operations. It is important that amendments to the hazard areas be communicated to personnel when tasks or operations change.

Appendix A: Subject Wellbore Schematics

Sample Subject Well fracture stimulation through casing schematic.

* O = Open, C = Closed

Subject Well

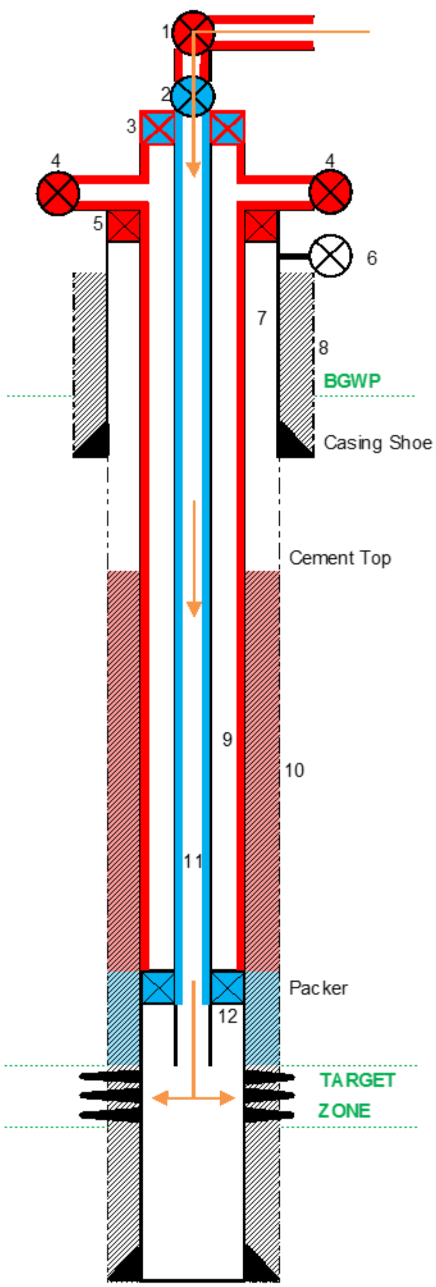


Well Barrier Element (WBE)	OEM Capacity (MPa)	Adjusted Max Pressure (MPa)	WBE Status *(O / C)
Primary Barrier Envelope			
2. Wellhead isolation valve			
3. Casing valve			
4. Wellhead (Production casing seals)			
8. Production casing (burst)			
9. Production casing cement			
Secondary Barrier Envelope			
1. Pumping company valve			
3. Casing valve			
4. Wellhead (Production casing seals)			
5. Surface casing valve			
6. Surface casing (burst)			
7. Surface casing cement			
Surface casing shoe (FIT)			

Direction of Flow : →

Sample Subject Well fracture string completion schematic.

Subject Well



* O = Open, C = Closed

Well Barrier Element (WBE)	OEM Capacity (MPa)	Adjusted Max Pressure (MPa)	WBE Status *(O / C)
Primary Barrier Envelope			
2. Wellhead isolation valve			
3. Tubing hanger seals			
11. Tubing (burst)			
12. Packer			
9. Production casing (burst)			
10. Production casing cement			
Secondary Barrier Envelope			
1. Pumping company valve			
3. Tubing hanger seals			
4. Casing valve			
5. Wellhead (Production casing seals)			
9. Production casing (burst)			
10. Production casing cement			

Direction of Flow : →

Appendix B: Casing Burst and Collapse Considerations

IRP 24 presupposes that a well design and casing are in place before a fracture stimulation program is developed. A review of existing well design and casing is necessary to understand the limitations of the casing (pipe and connections).

In all new wells, the well design and casing should be chosen based on all activities expected through the life of the well. This includes drilling, completion, fracture stimulation, production and abandonment requirements. A life cycle approach ensures the well is designed for all activities expected on the well not only the stimulation.

Factors Influencing Maximum Allowable Loads

Consider the following factors that may reduce the maximum allowable load below the OEM pressure rating:

- faulting, such as shear or pressure communication
- erosion
- corrosion
- partial pressure (pp) H_2S (influences barrier metallurgy requirements or performance as required in *AER Directive 010*)
    - pp H_2S < 0.3 kPa (Minimum Safety Factor Burst = 1.10)
      Note. This includes other grades not included in D010 such as P110.
    - 0.3 ≤ pp H_2S ≤ 10 kPa (Minimum Safety Factor Burst = 1.20)
    - pp H_2S > 10 kPa (Minimum Safety Factor Burst = 1.25)
- bending loads (refers to the load from wellbore trajectory or Dog Leg Severity (DLS) and axial buckling loads)
- axial loads (refers to load due to gravity, drag placing pipe in hole, tension level while setting slips, thermal expansion or contraction from the difference in static temperature, varying stimulation fluid temperature / density, and axial-hoop forces generated by internal pressure)
- torsion load

- thermal load (refers to loads caused by changes in tubular temperature at any point downhole during wellbore operations)
- temperature (including impacts on casing material properties and loading)
- hydraulic isolation in regards to cement integrity

Barrier Metallurgy

The type of material that comprises the casing is significant with respect to planned fracturing operations and expected production period of the well. Consider whether the well is expected to be:

- Sweet through life of well (see API 5CT[7], API TR 5C3[8] or AER D010[9] for acceptable casing material)
- Sweet during fracture operations with potential to become sour during production life (see AER D010 for casing material recommendations)
- Sour during fracture operations and production in which case AER D010 casing material is required. IRP 1[10] specifies casing materials that are required for critical sour wells or pp H_2S > 3500 kPa

[7] American Petroleum Institute, API Specification 5CT: Specification for Casing and Tubing http://www.api.org/~/media/files/certification/monogram-apiqr/program-updates/5ct-9th-edition-purch-guidelines-r1-20120429.pdf

[8] American Petroleum Institute, API TR 5C3: Technical Report on Equations and Calculations for Casing, Tubing, and Line Pipe Used as Casing or Tubing; and Performance Properties Tables for Casing and Tubing, First Edition: http://www.techstreet.com/api/searches/10363623

[9] Alberta Energy Regulator, Directive 010: Minimum Casing Design Requirements: http://www.aer.ca/rules-and-regulations/directives/directive-010

[10] DACC Industry Recommended Practice 1: Critical Sour Drilling: http://www.enform.ca/resources/detail/15/dacc-irp-volume-01-critical-sour-drilling

Calculations

The calculations below present one methodology to arrive at the burst and collapse Adjusted Maximum Pressure (AMP) ratings and planned pressure loading.

Barrier Element Burst and Collapse

With consideration given to the factors influencing maximum allowable loads mentioned above, barrier element burst and collapse may be calculated as described below (see footnotes above for additional references). In the equations, OEM refers to Original Equipment Manufacturer rating.

Barrier Element Burst$_{AMP}$ *= OEM Burst - Burst reduction due to factors above*

Barrier Element Collapse$_{AMP}$ *= OEM Collapse - Collapse reduction due to factors above*

Envelope Burst and Collapse

The envelope is one or more barrier elements that prevent fluids from flowing unintentionally from the formation into the wellbore, into another formation or to the external environment. Envelope AMP may be calculated as described below:

Envelope Burst$_{AMP}$ *(EB*$_{AMP}$*) = Lowest Barrier Burst*$_{AMP}$

Envelope Collapse$_{AMP}$ *(EC*$_{AMP}$*) = Lowest Barrier Collapse*$_{AMP}$

Maximum Burst and Collapse Pressures

Maximum burst and collapse pressures for the fracture stimulation design can be calculated according to the following:

$$Burst\ Pressure_{max} = STP_{max} + HDP_{max} + Pulse\ Pressure$$

$$Collapse\ Pressure_{max} = BHTP - HP_{min}$$

Maximum Surface Treating Pressure (STP_{max}) depends on the set point and the type of stop pumping control or relief system:

- Operator Controlled (Manual Stops)
    - $STP_{max} = Set\ Stop\ pump\ Pressure + Reaction\ time\ error$
- Electronic Controlled (Instrument Stops)
    - $STP_{max} = Set\ Stop\ pump\ Pressure + Instrument\ Error$
- Mechanical Relief
    - $STP_{max} = Set\ Mechanical\ Relief\ Pressure + Instrument\ Error$

Variables in the equation above are defined as follows:

STP_{max}	Maximum Surface Treating Pressure (just before screen out)
$BHTP$	Bottom Hole Treating Pressure (Fracture pressure plus pressure losses outside the envelope (e.g. tortuosity, perforation friction)
HP_{min}	Minimum Internal Hydrostatic Pressure (calculated from the lesser of base fluid density or flowback gas column)
HP_{max}	Maximum Internal Hydrostatic Pressure (calculated from the highest slurry density)
HDP_{max}	The maximum hydrostatic pressure difference at any depth between HP_{max} and the estimated formation pressure of any exposed permeable zone.
Pulse Pressure	The result of the change in fluid momentum and depends on the velocity, density, and time for the fluid to decelerate or stop. Barrier (e.g., casing string) expansion, fluid compressibility and leak-off will reduce pulse pressure.

Note. Electronic or manual shut down or mechanical relief pressure is typically set a few MPa higher than the anticipated surface working pressure.

Appendix C: Modeling Fracture Half-Length

The fracture half-length (X_f) is the lateral distance initiated from the Subject Wellbore to the <u>outer</u> tip of a fracture propagated by hydraulic fracturing. The fracture half-length (X_f) is also the maximum extent of the influence of the subsurface interaction by an induced fracture. There is a risk of underestimating X_f.

X_f determination is an estimate. To achieve a reasonable estimation in determining X_f using modeling, a combination of log measurements, physical measurements and/or a meaningful statistical proximal dataset needs to be used.

A log suite for data collection may be used to assist data collection. It may consist of triple combo (gamma ray, density and neutron) or dipole sonic. Supplementary measurements may include: geomechanical rock properties, fracture image logs, seismic, fluid efficiency, combined with reasonably accurate determination of reservoir pressure and permeability. Further considerations include more direct measurements of fracture propagation such as offset pressure, micro-seismic, and deformation (tiltmeters).

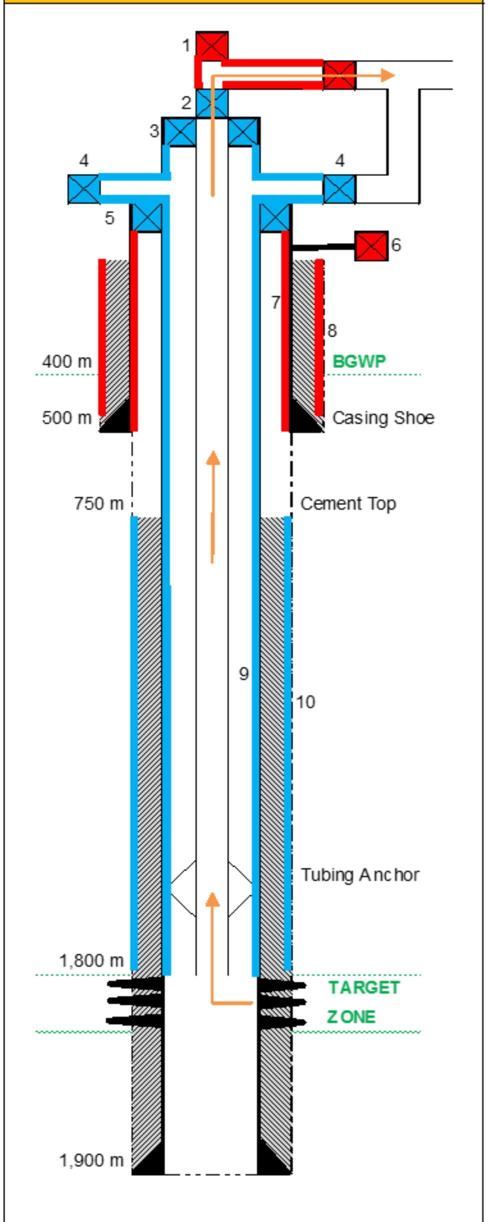
The following is a list of scenarios (not necessarily comprehensive) in which X_f may be underestimated.

- closure stress in bounding layer (stress contrast) is underestimated
- stress anisotropy ($O'h_{min}$ vs. $O'h_{max}$) is underestimated
- horizontal bedding plane failure is underestimated (i.e., fracture is more contained than expected due to difficulty propagating vertically across bedding planes)
- percentage of horizontal fracture development is overestimated
- Young's Modulus in zone of interest is underestimated
- fracture complexity is overestimated
- reservoir permeability is overestimated
- viscosity of the fluid is overestimated
- pay height is overestimated
- total fluid volume is underestimated

- anticipated multiple fractures taking fluid and only one fracture receives the total volume
- presence of natural fractures is underestimated or overestimated
- fluid leak-off rate is overestimated
- cross-linked fluid system break is delayed
- hydraulic fracture unintentionally contacts existing fault(s) or fractures
- lower than expected injection rate (slower rates generally result in longer, better contained fracs, all other variables being the same)
- increase in Young's modulus with applied stress during pumping (induced stiffening) is underestimated.

Appendix D: Sample IOW Barrier Schematic

Identified Offset Well



Barrier Elements	OEM Capacity (MPa)	Adjusted Max Pressure (MPa)	Barrier Status *(O / C)	IOW Monitored (Y / N)
Primary Barrier Envelope				
2. Rod BOP				
3. Tubing hanger seals				
4. Casing valve				
5. Secondary seals				
9. Production casing				
Secondary Barrier Envelope				
1. Stuffing box				
6. Surface casing vent valve				
7. Surface casing				
8. Surface casing cement				

Direction of Flow : →

Acronyms

AER	Alberta Energy Regulator
ALARP	As Low As is Reasonably Practical
AMP	Adjusted Maximum Pressure
CAPP	Canadian Association of Petroleum Producers
DACC	Drilling and Completions Committee
ERP	Emergency Response Plan
FPZ	Fracture Planning Zone
FSHMP	Fracture Stimulation Hazard Management Process
ICHMP	Interwellbore Communication Hazard Management Process
IOW	Identified Offset Well
IRP	Industry Recommended Practice
SCW	Special Consideration Wellbore
SHMP	Surface Hazard Management Process
SW	Subject Well
SWIHMP	Subject Well Integrity Hazard Management Process

Glossary

Active Downhole Operations

Drilling and well servicing operations (which may include multiple Operators) on any IOW that may occur during the planned fracture stimulation operation on the Subject Well.

Adjusted Maximum Pressure

A pressure determined by analyzing a barrier's original manufacture's equipment specification / rating and then reducing this original pressure rating by compensating for age and service. This pressure is determined at the Operator's discretion and in alignment with its risk tolerance.

As Low As Is Reasonably Practicable (ALARP)

The concept of "reasonably practicable" which involves weighing a risk against the trouble, time and money needed to control the risk or the sacrifice needed to further reduce risk. It describes the level to which we expect to see workplace risks controlled. (See the UK Health and Safety Executive document ALARP "at a glance")

At-risk IOW

An Identified Offset Well (IOW) that penetrates the Subject Well's target zone or terminates near the Subject Well's target zone (see 24.3.3.1 Determine At-Risk IOWs).

Barrier Element

Refers to an individual equipment component or objects that together collectively comprise a barrier envelope

Barrier Envelope

Refers to one or more barrier elements that prevent fluids from flowing unintentionally from the formation into the wellbore, into another formation or to the external environment (see NORSOK D-10)

Blowout

An unintended flow of wellbore fluids (oil, gas, water, or other substance) to the surface that cannot be controlled by existing wellhead and/or blowout prevention equipment, or a well that is flowing from one formation to another formation(s) (underground blowout) that cannot be controlled by increasing the fluid density. Control can only be regained by installing additional and/or replacing existing surface equipment to allow shut-in or to permit the circulation of control fluids, or by drilling a relief well (see *ERCB Directive 056: Energy Development Applications and Schedules, Appendix 3*,).

Concurrent Operations

Any operation not associated with the current fracture stimulation operation, and occurring in close proximity to the Subject Well.

Energy Well

A well initially licensed for the purpose of petroleum energy development, not including water wells.

Fracture Half-Length (X_f)

The lateral distance initiated from the Subject Wellbore to the outer tip of a fracture propagated by fracturing. The fracture half-length (X_f) is also the maximum extent of the influence of the subsurface interaction by an induced fracture. (See 24.3.2.1 Fracture Planning Zone Determination)

Fracture Planning Zone (FPZ)

Defines a screening area around the Subject Well, making it possible to identify all Offset Wells proximal to the Subject Well that may require a risk assessment and a well control plan.

Fracture stimulation

A treatment performed above the fracture pressure of the reservoir formation to create a highly conductive flow path between the reservoir and the wellbore. (Adapted from Schlumberger Oilfield Glossary)

Fracture stimulation design

The creation of a plan for the fracture stimulation of the Subject Well. It is a process to analyze the set of conditions, needs and requirements to determine fracture geometry that optimizes fracture stimulation objectives.

Fracture stimulation program

The document that defines the procedures and requirements to meet the fracture stimulation design of the Subject Well. The fracture stimulation program includes, but is not limited to the following parameters:

- pressures
- base fluid types
- chemicals
- proppant type, size, concentration and tonnage
- rates
- volumes
- equipment

Fracture stimulation operation

The execution of the fracture stimulation program.

Geometry

See Hydraulic Fracture Geometry

Hazard

Something (e.g., an object, a property of a substance, a phenomenon or an activity) that can cause adverse effects (see UK Health and Safety Executive document ALARP "at a glance")

Hydraulic Fracture Geometry

The maximum lateral and vertical extension of hydraulic fluids as a result of fracture stimulation.

Identified Offset Wells (IOWs)

All Offset Wells within the Fracture Planning Zone (FPZ) plus all wells identified as Special Consideration Wells that require evaluation using the *IOW Risk Assessment* (see 24.3.3).

Identified Offset Well Operator

Refers to the Operator of an Offset Well within the Fracture Planning Zone (FPZ) or a Special Consideration Well determined during the *IOW Risk Assessment* (see 24.3.3). In the case of a well that has no legally responsible or financially able Operating Company, the Orphan Well Association or the AER is considered the Identified Offset Well Operator.

IOW Well Control Plan

A comprehensive plan developed for at-risk IOW to avoid or control the risk of a well control event.

Interwellbore Communication

Interwellbore communication is defined as fluid and/or pressure communication event at an Offset Well during a fracture stimulation operation on a Subject Well.

Iron

The term iron in "Treating Iron", "Iron Management" or "Fracturing Iron" refers to the high pressure tubulars used in fracturing operations. The treating iron extends from the fluid end discharge on the horsepower units to the wellhead (see Figure 7). It includes all piping, connections and components (valves, manifolds, straight joints, and swivels, etc), and is normally made for a minimum of (69MPa) 10,000 psi Working Pressure.

Licensee

(Also known as "permit holder" in BC) The holder of a facility, pipeline, or well license according to the records of the Alberta Energy Regulator (AER); includes a trustee or receiver-manager of property of a Licensee (see *AER Directive 056: Energy Development Applications and Schedules, Appendix 3*). In Saskatchewan as defined in *The Oil and Gas Conservation Act*, a licensee means a person who holds a license and includes a trustee or receiver-manager of property of a licensee.

Maximum Treatment Pressure

Highest pressure permissible during fracture stimulation operations.

Offset Well

Any wellbore that is proximal to the Subject Well.

Operator

A person or company that has control of or undertakes the day-to-day operations and activities of a facility, pipeline, or well, whether or not that person is also the Licensee for the facility, pipeline, or well (see *ERCB Directive 056: Energy Development Applications and Schedules, Appendix 3*).

Orphan Well

According to the Orphan Well Association (www.orphanwell.ca), "in the upstream oil and gas industry, an orphan is a well, pipeline, facility or associated site which has been investigated and confirmed as not having any legally responsible or financially able party to deal with its abandonment and reclamation."

Primary Barrier Envelope

The first barrier envelope that prevents flow from a potential source of inflow (adapted from NORSOK Standard D-10).

Risk

The combination of the probability of an event and its consequences (from *ISO/IEC Guide 73:2002* definition 3.1.1 "Risk management – Vocabulary – Guidelines for use in standards")

Secondary Barrier Envelope

A second barrier envelope that prevents flow from a potential source of inflow (adapted from NORSOK Standard D-10)

Special Consideration Well (SCW)

Offset Wells proximal to the Subject Well beyond the FPZ that may have characteristics of unique concern which justifies further scrutiny

Subject Well

A well planned for fracture stimulation.

Subject well integrity

Prevention of the escape of fluids (i.e., liquids or gases) to subsurface formations or surface (see *ERCB Directive 083: Hydraulic Fracturing – Subsurface Integrity*).

Subject Wellsite Supervisor

The person responsible for the overall fracture stimulation operation at the Subject Well and responsible for the execution of the IOW Well Control Plan.

Subsurface Unintended Flow

A flow of wellbore fluids (oil, gas, water, or other substance) in the subsurface from one formation to another formation.

Surface Unintended Flow

An unmanaged flow of wellbore fluids (oil, gas, water, or other substance) at the surface that <u>can</u> be controlled by existing wellhead and/or blowout prevention equipment.

Surface Operations

All above ground activities that pertain to the fracture stimulation of the Subject Well.

Target Zone

The zone of interest to receive fracture stimulation in the Subject Well.

Well Control Event

A scenario in a well that may be a subsurface unintended flow, surface unintended flow, or a blowout.

Resources

There are many well researched and supported resources publically available regarding fracture stimulation, or hydraulic fracturing. Following are a few of the documents the IRP 24 working groups accessed during the development of this document:

AER: Directive 083: Hydraulic Fracture – Subsurface Integrity
http://www.aer.ca/rules-and-regulations/directives/directive-083

AER (2015). Subsurface Order No. 2: Monitoring and Reporting of Seismicity in the Vicinity of Hydraulic Fracturing Operations in the Duvernay Zone, Fox Creek, Alberta
https://www.aer.ca/documents/bulletins/Bulletin-2015-07.pdf

API HF1: Well Construction
http://www.api.org/oil-and-natural-gas-overview/exploration-and-production/hydraulic-fracturing/api_hf1_hydraulic_fracturing_operations

API HF2: Water Management
http://www.api.org/oil-and-natural-gas-overview/exploration-and-production/hydraulic-fracturing/api_hf2_water_management

API HF3: Practices for Mitigating Surface Impacts
http://www.api.org/oil-and-natural-gas-overview/exploration-and-production/hydraulic-fracturing/api_hf3_practices_for_mitigating_surface

BCOGC (2015). Defining: Induced Seismicity
https://www.bcogc.ca/node/12925/download

Canadian Society of Unconventional Resources
http://www.csur.com/resources

CAPP: Guiding Principles and Operating Practices for Hydraulic Fracturing
http://www.capp.ca/getdoc.aspx?DocId=218125

CAPP Hydraulic Fracturing Operating Practice: Anomalous Induced Seismicity: Assessment, Monitoring, Mitigation and Response
http://www.capp.ca/publications-and-statistics/publications/217532

DNV RP U301, Risk Management of Shale Gas Developments and Operations
http://www.dnvgl.com/rules-standards/

Fracfocus.org Publications includes George King's SPE paper *Hydraulic Fracturing 101* (SPE 152596)
http://fracfocus.org/publications

Fracopedia
http://www.oilandgasinfo.ca/fracopedia/

IRP 2 Volume 2: Completing and Servicing Critical Sour Wells
http://www.enform.ca/resources/detail/16/dacc-irp-volume-02-completing-and-servicing-critical-sour-wells

IRP Volume 4: Well Testing and Fluid Handling
http://www.enform.ca/safety_resources/publications/PublicationDetails.aspx?a=18&type=irp

IRP Volume 5: Minimum Wellhead Requirements
http://www.enform.ca/resources/detail/19/dacc-irp-volume-05-minimum-wellhead-requirements

IRP Volume 7: Standards for Wellsite Supervision of Drilling, Completion and Workovers
http://www.enform.ca/resources/detail/21/dacc-irp-volume-07-standards-for-wellsite-supervision-of-drilling-completion-and-workovers

IRP Volume 8: Pumping of Flammable Fluids
http://www.enform.ca/safety_resources/publications/PublicationDetails.aspx?a=22&type=irp

IRP Volume 13: Slickline Operations
http://www.enform.ca/resources/detail/23/dacc-irp-volume-13-slickline-operations

IRP Volume 20: Wellsite Design Spacing Requirements
http://www.enform.ca/safety_resources/publications/PublicationDetails.aspx?a=26&type=irp

IRP Volume 21: Coiled Tubing Operations
http://www.enform.ca/resources/detail/23/dacc-irp-volume-13-slickline-operations

IRP Volume 25: Primary and Remedial Cementing Guidelines
http://www.enform.ca/resources/detail/61/dacc-irp-volume-25-primary-and-remedial-cementing-guidelines

IRP Volume 25: Primary and Remedial Cementing Guidelines
http://www.enform.ca/safety_resources/publications/PublicationDetails.aspx?a=61&type=irp

NORSOK D-10: Well integrity in drilling and well operations
https://www.standard.no/en/sectors/energi-og-klima/petroleum/norsok-standard-categories/d-drilling/d-0104/

PSAC Working Energy Code of Conduct
http://www.oilandgasinfo.ca/working-energy-commitment/

The Modern Practices of Hydraulic Fracturing: A Focus on Canadian Resources
http://www.ptac.org/projects/142