Hydraulic fracturing design and operations guidelines

These guidelines set out the Ministry of National Infrastructure, Energy, and Water Resources (MNIEWR) requirements for hydraulic fracturing design and operations. All the requirements and assigned limits shall be applied during design and operations of well-tests with injection pressure higher than formation pressure.

These guidelines are based in part on the Canadian Directive 083: Hydraulic Fracturing – Subsurface Integrity; they also incorporate API standards that are relevant to the guidelines: http://www.api.org/~/media/files/policy/exploration/hydraulic_fracturing_infosheet.pdf.

These guidelines are intended to:

a) Standardize procedures for hydrofrac operation planning, submission of Hydrofrac Program, operations' result and End Operation report to MNIEWR,
b) Optimize result of hydrofrac by using accurate design,
c) Investigate result of hydrofrac using post hydrofrac tests and/or monitoring,
d) Prevent loss of well integrity at a subject well (a well at which a licensee proposes to conduct hydraulic fracturing operations),
e) Reduce the likelihood of unintentional inter-wellbore communication between a subject well and an offset well,
f) Manage well-control at an offset well in the event of interwellbore communication with a subject well,
g) Prevent adverse effects on non-saline aquifers,
h) Prevent impacts on water wells, and
i) Prevent surface impacts.

These guidelines contain:

a. Introduction (section 1),
b. Hydrofrac design requirements (section 2),
c. Requirements for pre/post job reporting and raw data supply (section 2),
d. Requirements for preventing loss of well integrity at a subject well (section 3),
e. Requirements for licensees to assess, plan for, and mitigate the risks of interwellbore communication with offset wells (section 4),
f. Requirements to notify licensees of at-risk offset wells about hydraulic fracturing operations (section 4.3),
g. Prohibition of hydraulic fracturing operations if the distance between the induced fracture-zones multiplied by a safety factor of 2, and the top of the waterbearing formation is less than 100 m (section 2 and 5),
h. Increased vertical depth restriction for hydraulic fracturing operations near water wells (section 6),
i. Increased vertical depth restriction for hydraulic fracturing operations near the top of the bedrock surface (section 7),
j. Pumping-volume restrictions and provisions for to notify the MNIEWR about hydraulic fracturing operations (section 9).

Hydraulic fracturing design and operations guidelines

1. INTRODUCTION ........................................................................................................5
  1.1 Purpose of These Guidelines ..............................................................................5
  1.2 Implementation Date for Guidelines Requirements ............................................5
  1.3 Compliance Assurance .......................................................................................5

2. MAJOR REQUIREMENTS ..........................................................................................6
  2.1 Applications for hydraulic fracturing: .................................................................6
  2.2 General requirements for right holders ...............................................................6
  2.3 Procedure of hydraulic fracturing: ......................................................................7

3. WELL INTEGRITY – SUBJECT WELL .................................................................10
  3.1 Issue ....................................................................................................................10
  3.2 Regulatory Objective ........................................................................................10
  3.3 Requirements ....................................................................................................10

4. INTER-WELLBORE COMMUNICATION ............................................................12
Hydraulic fracturing design and operations guidelines

Figure 1 - Example of a simplified dual-barrier system............................................. 11
Figure 2 - Example of a single-barrier system............................................................. 11
Figure 3 - Hydraulic fracturing near water wells......................................................... 15
Figure 4 - Hydraulic fracturing near top of bedrock.................................................... 16
Hydraulic fracturing design and operations guidelines

1. Introduction

1.1 Purpose of These Guidelines

These guidelines set out the Ministry of National Infrastructures, Energy, and Water Resources (MNIEWR) requirements for Hydraulic fracturing design and operations. These guidelines do not apply to thermal wells. All the requirements and assigned limits described below shall be applied while design and operations of wells tests with injection pressure higher than formation pressure.

1.1.1 These requirements are intended to

j) standardize of procedures of hydrofrac operation planning, submission of Hydrofrac Program, operations' result and End Operation report to MNIEWR,

k) optimize result of hydrofrac by accurate design,

l) investigation of result of hydrofrac by post hydrofrac tests and/or monitoring,

m) prevent the loss of well integrity at a subject well (a well at which a licensee proposes to conduct hydraulic fracturing operations),

n) reduce the likelihood of unintentional inter-wellbore communication between a subject well and an offset well,

o) manage well control at an offset well in the event of inter-wellbore communication with a subject well,

p) prevent adverse effects to non-saline aquifers,

q) prevent impacts to water wells, and

r) prevent surface impacts.

1.1.2 These guidelines include

a) introduction (section 1),

b) requirements to hydrofrac design (section 2),

c) requirements to pre/post job reporting and raw data supply (section 2),

d) requirements to prevent the loss of well integrity at a subject well (section 3),

e) requirements for licensees to assess, plan for, and mitigate the risks of interwellbore communication with offset wells (section 4),

f) requirements to notify licensees of at-risk offset wells related to hydraulic fracturing operations (section 4.3),

h) forbbindance of hydraulic fracturing operations if the distance between induced fractures zone multiplied on factor 2 till top of waterbearing formation less than 100 m (section 2 and 5),

i) increased vertical depth restriction for hydraulic fracturing operations near water wells (section 6),

j) increased vertical depth restriction for hydraulic fracturing operations near the top of the bedrock surface (section 7),

k) pumping-volume restrictions and provisions to setback distances for nitrogen fracturing operations for coalbed methane (section 8), and

l) requirements to notify the MNIEWR about hydraulic fracturing operations (section 9).

1.2 Implementation Date for Guidelines Requirements

The requirements of these guidelines are effective December 15, 2015.

1.3 Compliance Assurance
The term “must”/"shall" indicates MNIEWR requirements for which compliance is required and is subject to MNIEWR enforcement. The terms “recommends” or “expects” indicate recommended practices and are not subject to enforcement action.

In its assessment of licensees’ compliance with the requirements of these guidelines, the MNIEWR may at any time request licensees to produce those documents, records, or plans required to be completed by these guidelines, and licensees must provide them to the MNIEWR. If the MNIEWR determines that the documentation is incomplete, insufficient, or that additional documentation is needed to support licensees’ compliance with the regulatory objectives in these guidelines, licensees may be required to provide additional documentation prior to conducting its hydraulic fracturing operation. The MNIEWR recommends that all documentation be kept on file for the life of the well.

2. **Major requirements**

Hydraulic fracture treatments are used to increase the productivity index of a producing well or the injectivity index of an injection well. The productivity index defines the rate at which oil or gas can be produced at a given pressure differential between the reservoir and the wellbore, while the injectivity index refers to the rate at which fluid can be injected into a well at a given pressure differential. Hydraulic fracturing is a process in which pressure is applied to a reservoir rock on purpose in order to break or crack it. These cracks are called hydraulic fractures. Most hydraulic and natural fractures are near vertical and increase well productivity significantly.

2.1 **Applications for hydraulic fracturing:**

- Increase the flow rate of oil and/or gas from low-permeability reservoirs
- Increase the flow rate of oil and/or gas from wells that have been damaged
- Connect the natural fractures and/or cleats in a formation to the wellbore
- Decrease the pressure drop around the well to minimize sand production
- Enhance gravel-packing sand placement
- Decrease the pressure drop around the well to minimize problems with asphaltine and/or paraffin deposition
- Increase the area of drainage or the amount of formation in contact with the wellbore
- Connect the full vertical extent of a reservoir to a slanted or horizontal well.

2.2 **General requirements for right holders.**

- Hydrofrac operation shall not be implemented by Right Holder till written permit of MNIEWR will not be received based on Hydrofrac Program done in accordance with on present Guidelines requirements. Hydrofrac Program shall be submitted
Hydraulic fracturing design and operations guidelines

to MNIEWR min 30 days before the operation. MNIEWR has right to revoke the program, to request to change conditions.

- FDP, Drilling programs on low permeability formation (lower than 10 mD for oil wells and 1mD for gas well) will not be accepted by MNIEWR without plan on operations on increasing productivity index.

- Hydrofracturing should be considered for increasing production rates not only on low permeability formations but when it is feasible, efficient (like drainage of laminated formation, sands control etc.) and not risky. Other methods of productivity index increase shall also be considered by Right Holder to maximize recovery factor while limitation of risks.

- Hydrofrac design, hydrofrac operations, post-frac formation testing and result monitoring and analysis shall be inline with the descriptions below and made based on qualified data set, described below as well. Hydrofrac design shall include risk and uncertainty analysis.

- Decision about hydrofrac operation (and variant of design) shall be taken by Right Holder on the base of it production/commercial efficiency and minimization of the risks and it shall be presented to MNIEWR.

- MNIEWR may to request Right Holder to plan hydrofrac operations and decision about hydrofrac operation will be taken on the base of production/commercial efficiency and risks.

- Together with Hydrofrac Program Right Holder must submit to MNIEWR the report of quality of well casing.

- After receiving of written permit on Hydrofrac Operation from MNIEW, Right Holder could start the treatment and all the details shall be reported daily and the process and the result, plan –fact analysis of Hydrofrac shall be send to MNIEWR not later than 30 days after finalization of hydrofrac operation. Specific requirements to operations described at Clause 3 and below.

- End Operational report shall include details of Hydrofrac operation and plan-fact analysis, result of hydrofrac analysis based on post-frac well test or monitoring of frac and after-frac well activity. Result of the measurements and tests shall be accompanied with raw data in Excel format and the result of data interpretation shall be added to End of Operational report and send to MNIEWR not later then 90 days after finalization of hydrofrac operation and post-frac test.

2.3 Procedure of hydraulic fracturing:

2.3.1 Decision of hydraulic fracturing shall be taken based on prediction of production incremental rate after operation and economical efficiency evaluation. Evaluation conducting for all wells-candidates for hydrofrac based on at least sector geological, dynamic and geomechanical reservoir models and on the information listed below, so accurate core analysis, logging, RCI, well test and their interpretation shall be done prior. All raw data, result of their interpretation and modeling with illustration of following parameters shall be presented to MNIEWR in (together and as the part) with Hydrofrac program:

a) Geological vision,

b) Topographical maps with all cultural elements and water wells locations (with aquifer depth). If the distance between well –candidate for Hydrofrac and water well less then 1000 meters in depth and by lateraly, detail geological description of whole section lower than seal layer of waterbearing horizon, or
Hydraulic fracturing design and operations guidelines

if waterbearing horizon is below interval for hydraulic fracturing then the description shall cover whole section below 100 m of waterbearing horizon. Geological description shall include lithofacial and petrophysical properties of each of formation, structural features of the area, including tectonic history, quality of the seals which separate target interval for hydrofrac from water bearing horizon. Undependently on distance to waterbearing formation, structural and lithofacial models shall be presented (structural maps with faults, lithological boundary, lithofacial description) till target horizon +100 m.

c) Target Formation permeability and porosity,
d) Target Formation compressibility,
e) Elastic modules,
f) Reservoir fluid viscosity,
g) Skin factor at target interval,
h) Reservoir pressure (initial and current),
i) Reservoir depth,
j) Reservoir thinkness,
k) The condition of the wellbore,
l) Formation water properties,
m) Oil (gas) water contact,
n) Reservoir seal and caprock properties,
o) Production and workover history, production analysis,
p) Well casing design and quality of casing,
q) Geological sector model,
r) Dynamic sector model,
s) Induced and natural fractures description & characteristic (observed from image logs, core, drilling data, well test result, seismic attributes etc) and geomechanical reservoir models, including overburden pressure, horizontal stress and anisotropy, expected fracture pressure gradient, pressure of fracture creation at target formations.

2.3.2 Hydrofrac program shall describe: design of Hydrofrac, prefrac casing tests, frac operations, post-frac test and hydrofrac monitoring (if it is applicable), answers on QHSE questions:

2.3.3 Design of Hydrofrac. The goal of every fracture treatment design includes optimization of propped fractures geometry and conductivity: length, width, height, permeability and the drainage area. While geomechanical modeling, the quality of seals should be taken into account to predict radius of hydrofrac distribution. Options of stimulation shall be prepared and each should include:

a) Composition and properties of pumping fluid, rate and volume of pumping fluid; expected value of fracture half-length, width, height, direction, also, fluid transportation and expected leaking. Four considerations govern fluid selection and choice of properties of fluid and pumping pressure: creation of planned fractures; minimization of damage as low as possible; protection from fluid loss; low friction pressure drop. Most fracture treatments should be pumped with suitable water-base fracture fluids. Acid-base fluids can be used in some case (concentration and content shall be choosen and approved ONLY after proper acidation test based on core data); Oil-base fluids should be used only in oil reservoirs when water-base fluids have proved conclusively do not work. Because of pumping oil-base fluids and acid are more dangerous than pumping water-base fluids, special care should be taken while planning and during the
operation. The necessity of usage of such fluids, including chemicals for "breaking" fluid and possible negative impact while usage of such fluids should be demonstrated in Hydrofrac Program.

a) Propped fractures width, height and length/radius of distribution, permeability and concentration of proppant in fractures, physical properties of the proppants (strength, grainsize, density etc.) and proppant volume, closure stress, expected fracture conductivity, contaminants. And, expectation of reduction of fractures conductivity in future related to propping agent properties. Modelled vertical distance from induced fractures zone multiplied by a factor of two till waterbearing layer shall be more then 100m (for min case).

b) Gravel pack. At many reasons of treatment application of gravel pack is preferable or needed (gives lower average skin values, the high production rates and sand control). But this method could not be applied at all the situations, so, should be considered it is appropriate solution at each particular case.

c) Production forecast.

2.3.4 Uncertainty and risk analysis. Uncertainty should be included into Hydrofrac program to prove chosen variant of hydrofrac treatment. Uncertainty should be evaluated with taking account of uncertainty of input parameters to the models, like uncertainty of in-situ stress, Poisson and Young's modulus, permeability or fluid-loss. The design should acknowledge these uncertainties and make sensitivity runs with the fracture-propagation model to determine the effect of these uncertainties on the design process. Permit holder should evaluate risks such as:

a) Mechanical risks - mechanical problems with the well or the surface equipment cause the treatment to fail.

b) Product price risks - risk of the situation that hydraulic fracturing is executed and paid for (i.e., the money is spent), but the well does not produce at the desired flow rates nor achieve the expected cumulative recovery.

c) Geologic risks - uncertainty of geological data should be counted as main reason of lost of efficiency of operations.

d) Environment damage and other similar risks. Important to understand penetration of the liquid outside the reservoir.

2.3.5 Cost and economic efficiency evaluation. Economical evaluation determines the optimum fracture treatment design. Decision of frac design will be taken based on comparison of the variants of costs of the treatment with benefit came from increase of hydrocarbon volume at the result of the treatment with minimal risks.

2.3.6 All operation aspect of Hydrofrac described at all the details below (at item 3 and below).

2.3.7 Hydrofrac operation should be checked at on-line regime. The data should be reported.

2.3.8 Post frac operations:

a) Post frac wells test/measurements into the wells. Raw data of post-frac well tests result, result of data interpretation and final report of conducted tests or other measurements should be included in End Operational report.

b) Microseismic monitoring of hydrofracturing operations. In some case it could be required activity. At this case monitoring technology, design and details of monitoring process should be presented in Hydrofrac program. Raw data of hydrofrac monitoring and their interpretation should be included in End Operational report.
3. Well Integrity – Subject Well

3.1 Issue
During hydraulic fracturing operations, subject wells can incur significant stresses, which may lead to a loss of well integrity. A loss of well integrity may result in subsurface impacts or result in a release of fluids to the surface, placing the public and the environment at risk.

3.2 Regulatory Objective
To prevent the loss of well integrity at a subject well.

3.3 Requirements
3.3.1 General
a) Licensees must design, construct, and operate its well to provide well integrity during hydraulic fracturing operations.
b) Licensees must obtain MNIEWR approval if using a single- or dual-barrier system as described below, or a barrier system other than a single- or dual-barrier system. Licensees are expected to manage well integrity throughout the life of the well, from construction to post abandonment.

3.3.2 Dual-barrier System
a) If a dual-barrier system (see Figure 1) is used, it must consist of
   • a primary barrier system capable of containing and isolating the fracture fluids,
   • a secondary barrier system capable of providing well control in the event of a failure of the primary barrier, and
   • a monitoring system to detect and allow for a response to a primary barrier failure.
b) To be classified as a dual-barrier system, the cement of the primary barrier system must not extend above the base of the overlying porous interval.
3.3.3 Single-barrier System

The MNIEWR expects licensees to apply increased diligence in designing a single-barrier system (see Figure 2). When using a single-barrier system, surface casing must be set in accordance with the current requirements of Directive 008: Surface Casing Depth Requirements.

a) If surface casing is not set to the BGWP, licensees must
   • not use hydraulic fracturing fluids that may cause an adverse effect on non-saline aquifers and
   • cement the next casing string to surface.
b) If a single-barrier system is used, licensees must
   • document the load capacity and safety factors used in the design of its casing relative to the loads and the well environment that the casing will be exposed to,
   • document the adjusted maximum pressure,
   • use an operating practice, such as the Primary and Remedial Cementing Guidelines (Drilling and Completions Committee) or a technically equivalent standard, when planning and executing its cementing program,
   • be able to demonstrate integrity of both casing and cement prior to initial fracture operations,
   • be able to demonstrate integrity of casing during fracture operations,
   • be able to demonstrate integrity of casing with final completion operations or within 90 days of the fracture operation,
   • test the production casing to a pressure that is adequate to meet the well’s operational objectives (which should include potential pressures during fracturing operations) prior to perforating and hydraulic fracturing operations and
   • conduct a surface casing vent flow / gas migration test (as per Interim Directive 2003-01: Isolation Packer Testing, Reporting, and Repair Requirements; Surface Casing Vent Flow/Gas Migration Testing, Reporting, and Repair Requirements; Casing Failure Reporting and Repair Requirements, or a surface casing annulus flow test (as per the attachment to Bulletin 2011-35: Surface Casing Vent Requirements for Wells)
     • prior to initial fracturing operations and
     • between 60 and 90 days after completing fracturing operations.

4. Inter-wellbore Communication

4.1 Issue
Inter-wellbore communication occurs when a communication pathway has been established between a subject well and an offset well. A communication pathway may cause a well control event at an offset well, which may result in subsurface impacts or a release of fluids to the surface, placing the public and the environment at risk.

4.2 Regulatory Objective
To reduce the likelihood of unintentional inter-wellbore communication between a subject well and an offset well.
To manage well control at an offset well in the event of inter-wellbore communication with a subject well.

4.3 Requirements
4.3.1 General
   a) Licensees must manage the risks of inter-wellbore communication between a subject well and an offset well.

4.3.2 Hydraulic Fracturing Risk Planning
   a) Licensees must have a documented hydraulic fracturing program.
   b) The hydraulic fracturing program must include the following elements:
      • determination of a fracture planning zone (FPZ),
Hydraulic fracturing design and operations guidelines

- identification of all offset wells within the FPZ,
- an assessment of well integrity for each offset well,
- a risk assessment for each offset well, using a methodology such as that described in Interim Industry Recommended Practice 24: Fracture Stimulation: Inter-wellbore Communication (IRP 24) (Drilling and Completions Committee),
- determination of at-risk offset wells within the FPZ,
- identification and assessment of special-consideration wells for possible inclusion in the well control plan, and
- identification of energizing gas(es) used in fracture fluids.

c) Licensees must maintain a copy of its hydraulic fracturing program at the subject well site for the duration of the operation.

The use of high vapour pressure hydrocarbons requires prior approval by the MNIEWR.

Licensees should be aware of any subsurface features such as those described, for example, in IRP 24 Hazard Register.

4.3.3 At-risk Offset Well Control Plans

a) Licensees must have a documented well control plan for each at-risk offset well that includes
- the method(s) of detection of inter-wellbore communication,
- how information will be relayed from an at-risk offset well back to the hydraulic,
- fracturing operations should an inter-wellbore communication event occur,
- the adjusted maximum pressure for each at-risk offset well, and
- how the licensee will ensure well control at each at-risk offset well.

b) Licensees must maintain a copy of its at-risk offset well control plan at the subject well site for the duration of the hydraulic fracturing operation.

4.3.4 Subject Well / At-risk Offset Well Licensee Engagement

a) Licensees must notify licensees of at-risk offset wells of its planned hydraulic fracturing program.

Upon notification of a planned hydraulic fracturing program, licensees of at-risk offset wells are expected to engage and work cooperatively with licensees of subject wells in the development of well control plans.

b) Licensees must engage licensees of at-risk offset wells and make all reasonable efforts to develop mutually acceptable well control plans.

c) Licensees of both offset and subject wells are responsible for maintaining control of its licensed wells at all times.

d) If the at-risk offset well does not have an active licensee, and it is not an orphan well, licensees must contact the MNIEWR representative.

e) Upon becoming aware of any communication event with an offset well, licensees must immediately notify the licensee of the offset well.

Additional MNIEWR notification requirements are found in section 9.
5  **Nonsaline Aquifer Protection**

5.1  **Issue**  
Communication between the subject well and a nonsaline aquifer as a result of hydraulic fracturing operations may cause adverse effects.

5.2  **Regulatory Objective**  
To prevent adverse effects to nonsaline aquifers.

5.3  **Requirements**

5.3.1  **General**

a) Licensees’ hydraulic fracturing operations must not have an adverse effect on a nonsaline aquifer.

5.3.2  **Nonsaline Aquifer Risk Assessment**

b) Licensees must not use hydraulic fracturing within 100 m above of the top of any nonsaline aquifers, or within 100 m below the BGWP.

c) A risk assessment must be prepared if conducting hydraulic fracturing operations above 500 m of the top of any nonsaline aquifers, or within 500 m below, the BGWP.

d) Licensees’ risk assessment must include the following:

   • an evaluation of the potential for direct fracture communication from the subject well to a nonsaline aquifer,
   • the true vertical depth (TVD) of the top and base of any nonsaline aquifers above the BGWP,
   • the TVD of the fracture interval(s) within the wellbore,
   • the modelled vertical fracture distance (i.e., vertical half length),
   • the minimum distance between vertical fracture propagation and the adjacent nonsaline aquifers along the entire fracture interval,
   • documentation of the procedure used to determine whether or not fracture fluid components may cause an adverse effect on nonsaline aquifers,
   • any geological feature or other pathways that may allow or facilitate communication to a nonsaline aquifer, and
   • mitigation measures to minimize the risk of adverse effects on nonsaline aquifers.

e) If the modelled vertical fracture distance multiplied by a factor of two is within 100 m below the BGWP, or is within 100 m above of the top of any nonsaline aquifers, licensees must not use hydraulic fracturing.

6  **Hydraulic Fracturing Near Water Wells**

6.1  **Issue**  
Communication between the subject well and water wells as a result of hydraulic fracturing operations may cause adverse effects.

6.2  **Regulatory Objective**  
To prevent impacts to water wells.

6.3  **Requirements**

a) Licensees’ hydraulic fracturing operations must not have an adverse effect on the water well’s water quality or quantity.
b) Licensees must not initiate hydraulic fracturing operations within a zone that extends 200 m horizontally from the surface location of a water well and 100 m vertically from the total depth of the water well (see Figure 3), except when using nitrogen as the fracturing fluid for coalbed methane completions (see section 8).

c) Licensees must not initiate hydraulic fracturing operations within a zone that extends 100 m horizontally from the surface location of a water well and 200 m vertically from the total depth of the water well.

Figure 3 - Hydraulic fracturing near water wells.

7 Hydraulic Fracturing Near Top of Bedrock

7.1 Issue
Fracture propagation during hydraulic fracturing operations may result in a release of fluids to the surface, placing the public and the environment at risk.

7.2 Regulatory Objective
To prevent surface impacts.

7.3 Requirements
a) Licensees’ hydraulic fracturing operations must not cause surface impacts.

b) Licensees must not hydraulically fracture within 100 vertical m of the top of the bedrock surface (see Figure 4), except when using nitrogen as the fracturing fluid for coalbed methane completions (see section 8).
Special Provisions for Coalbed Methane Fracturing
The requirements below are derived from an independent study with respect to using nitrogen as the fracturing fluid for coalbed methane completions (The report, Shallow Nitrogen Fracturing Dimensions and Groundwater Protection, outlining the findings of the study can be found on the landing page for Directive 027: Shallow Fracturing Operations-Restricted Operations on the ERCB website, www.ercb.ca.).

8.1 Coalbed Methane Fracturing Near Water Wells
a) Licensees must not initiate nitrogen fracturing operations within a zone that extends 200 m horizontally from the surface location of a water well to 50 m vertically from the total depth of the water well.

8.2 Coalbed Methane Fracturing Near Top of Bedrock
a) Licensees must not initiate nitrogen fracturing operations within 50 vertical m of the top of the bedrock surface.

8.3 Nitrogen Pumping Volume Limitations in Coals
a) Licensees must not use more than 15 000 standard cubic metres of nitrogen per vertical metre of coal.

9 MNIEWR Notification Requirements
a) Licensees must notify the MNIEWR a minimum of five days prior to the pressure test of surface equipment for hydraulic fracturing operations as per the Hydraulic Fracturing Notification Submission procedure found on the MNIEWR website at www.energy.gov.il. Notification is for one well licence or for a pad (multi-well) with continuous hydraulic fracturing operations.

b) If an operation is demobilized and remobilized at a later date, licensees must re-notify the MNIEWR via the Hydraulic Fracturing Notification Submission procedure a minimum of five days prior to the pressure test of surface equipment for hydraulic fracturing operations. Notification is for one well licence or for a pad (multi-well) with continuous hydraulic fracturing operations.
c) Licensees must immediately notify the MNIEWR if well integrity fails.

d) Licensees of the subject well must immediately notify the MNIEWR upon becoming aware of any communication event with an offset well, a nonsaline aquifer, or a water well.

10 Continual Improvement

It is recommended that all licensees continually improve the planning and execution of its hydraulic fracturing operations by evaluating the effectiveness of its operations in meeting the regulatory objectives of these guidelines and by revising the planning and execution of its subsequent hydraulic fracturing operations accordingly. Licensees are encouraged to document its continual improvement process using an appropriate procedure.
11 Environmental

11.1 Water Management
Water management associated with hydraulic fracturing shall be in accordance with "API GUIDANCE DOCUMENT HF2" and requirements of Israeli Water Authority.

11.2 Mitigating Surface Impacts
Practices for mitigating surface impacts associated with hydraulic fracturing shall be in accordance with "API GUIDANCE DOCUMENT HF3" and requirements of Israeli Ministry of Environmental Protection.

12 Safety and Fire protection
Process and occupational safety and fire protection measures associated with hydraulic fracturing shall be at least in accordance with API standards (appendix 4 on p.25), safety guidelines of MNIEWR, which published on the MNIEWR website, and requirements of District Fire Services.
### Appendix 1 – Definitions of Terms as used in These Guidelines

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Adjusted maximum pressure</strong></td>
<td>Operating pressure limits at the subject well and the offset wells, including a safety margin that will not be exceeded.</td>
</tr>
<tr>
<td><strong>Adverse effect</strong></td>
<td>Impairment of or damage to the environment, human health or safety or property.</td>
</tr>
<tr>
<td><strong>At-risk offset well</strong></td>
<td>An offset well that may be adversely affected by a hydraulic fracturing operation.</td>
</tr>
<tr>
<td><strong>Barrier</strong></td>
<td>Individual components that collectively make up a barrier system.</td>
</tr>
<tr>
<td><strong>Base of groundwater protection (BGWP)</strong></td>
<td>A modelled depth at which saline groundwater is likely to occur. It is calculated as the base of the deepest protected (nonsaline groundwater-bearing) formation plus a 15 m buffer.</td>
</tr>
<tr>
<td><strong>Bedrock</strong></td>
<td>Consolidated rock underlying unconsolidated glacial or drift material, or Solid rock either exposed at the surface or situated below surface soil, unconsolidated sediments and weathered rock.</td>
</tr>
<tr>
<td><strong>Dual-barrier system</strong></td>
<td>A well system designed for hydraulic fracturing operations made up of both primary and secondary barrier systems.</td>
</tr>
<tr>
<td><strong>Energizing gas</strong></td>
<td>A gas used to improve the effectiveness of the hydraulic fracture.</td>
</tr>
<tr>
<td><strong>Fracture planning zone (FPZ)</strong></td>
<td>An area that may be impacted by hydraulic fracturing operations (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).</td>
</tr>
<tr>
<td><strong>High vapour pressure hydrocarbon</strong></td>
<td>Any hydrocarbon and stabilized hydrocarbon mixture with a Reid vapour pressure greater than 14 kilopascals.</td>
</tr>
<tr>
<td><strong>Licensees</strong></td>
<td>For the purposes of these guidelines, the term “licensees” is used to designate the responsible duty holder (e.g., licensee, operator, company, applicant, approval holder, right holder) as specified in legislation, and refers to subject well licensees unless otherwise stated.</td>
</tr>
<tr>
<td><strong>Nonsaline aquifer</strong></td>
<td>An aquifer above the BGWP that contains water with a total dissolved solids content of less than or equal to 4000 milligrams per liter.</td>
</tr>
<tr>
<td><strong>Offset well</strong></td>
<td>Any well that is within the FPZ of a subject well, excluding water wells.</td>
</tr>
<tr>
<td><strong>Orphan well</strong></td>
<td>A well that has been designated by the MNIEWR as an orphan well.</td>
</tr>
<tr>
<td><strong>Primary barrier system</strong></td>
<td>A well system designed to contain and isolate fracture fluids within the well.</td>
</tr>
<tr>
<td><strong>Risk assessment</strong></td>
<td>Systematic analysis of the risks from activities and a rational evaluation of their significance by comparison against predetermined standards, target risk levels, or other risk criteria.</td>
</tr>
</tbody>
</table>
## Secondary barrier system
The backup well system that provides well control in the event of a failure of the primary barrier system.

### Single-barrier system
A well system designed for hydraulic fracturing operations comprised of a primary barrier system only.

### Special-consideration well
A well beyond the FPZ that may have characteristics of unique concern which justifies further scrutiny.

### Subject well
A well at which a licensee proposes to conduct hydraulic fracturing operations.

### Thermal well
A well that is completed in a reservoir that is, was, or has the potential to be artificially heated.

### Water well
A well with the primary purpose of nonsaline groundwater production or well that is connected to a public water system.

### Well control event
A flow of wellbore fluids in the subsurface from one formation to another formation, a flow of wellbore fluids at surface that can be controlled by existing wellhead or blowout prevention equipment, or a blowout.

### Well integrity
Prevention of the escape of fluids (i.e., liquids or gases) to subsurface formations or surface.
Appendix 2 – Chemicals are used within fracture fluids

Chemical additives perform many functions within fracture fluids. A Chemical Abstracts Service (CAS) Number is a unique identifier for chemical substances. The CAS is a division of the American Chemical Society that is responsible for the administration, quality assurance and maintenance of the CAS registry. A CAS Number itself has no inherent chemical significance but provides an unambiguous way to identify a chemical substance or molecular structure when there are many possible systematic, generic, proprietary or trade names. The number of chemical additives used in a typical fracture treatment depends on the conditions, such as depth or location, of the specific well being fractured and the characteristics of the formation, such as thickness and type of rock. A typical fracture treatment will use very low concentrations of between 3 and 12 additive chemicals, depending on the characteristics of the water and the rock formation being fractured. Each component serves a specific, engineered purpose.
## Hydraulic fracturing design and operations guidelines

<table>
<thead>
<tr>
<th>Product Function</th>
<th>Chemical Name</th>
<th>CAS</th>
<th>Chemical Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid</td>
<td>Hydrochloric Acid</td>
<td>007647-01-0</td>
<td>Helps dissolve minerals and initiate cracks in the rock</td>
</tr>
<tr>
<td>Biocide</td>
<td>Glutaraldehyde</td>
<td>000111-30-8</td>
<td>Eliminates bacteria in the water that produces corrosive by-products</td>
</tr>
<tr>
<td></td>
<td>Ammonium Chloride</td>
<td>012125-02-9</td>
<td>Eliminates bacteria in the water that produces corrosive by-products</td>
</tr>
<tr>
<td></td>
<td>Quaternary Ammonium Chloride</td>
<td>061789-71-1</td>
<td>Eliminates bacteria in the water that produces corrosive by-products</td>
</tr>
<tr>
<td></td>
<td>Tetrakis Hydroxymethyl-Phosphonium Sulphate</td>
<td>055566-30-8</td>
<td>Eliminates bacteria in the water that produces corrosive by-products</td>
</tr>
<tr>
<td>Breaker</td>
<td>Ammonium Persulphate</td>
<td>007727-54-0</td>
<td>Allows a delayed break down of the gel</td>
</tr>
<tr>
<td></td>
<td>Sodium Chloride</td>
<td>007647-14-5</td>
<td>Product Stabilizer</td>
</tr>
<tr>
<td></td>
<td>Magnesium Peroxide</td>
<td>014452-57-4</td>
<td>Allows a delayed break down of the gel</td>
</tr>
<tr>
<td></td>
<td>Magnesium Oxide</td>
<td>001309-48-4</td>
<td>Allows a delayed break down of the gel</td>
</tr>
<tr>
<td></td>
<td>Calcium Chloride</td>
<td>010043-52-4</td>
<td>Product Stabilizer</td>
</tr>
<tr>
<td>Clay Stabilizer</td>
<td>Choline Chloride</td>
<td>000067-48-1</td>
<td>Prevents clays from swelling or shifting</td>
</tr>
<tr>
<td></td>
<td>Tetramethyl ammonium chloride</td>
<td>000075-57-0</td>
<td>Prevents clays from swelling or shifting</td>
</tr>
<tr>
<td></td>
<td>Sodium Chloride</td>
<td>007647-14-5</td>
<td>Prevents clays from swelling or shifting</td>
</tr>
<tr>
<td>Corrosion Inhibitor</td>
<td>Isopropanol</td>
<td>000067-63-0</td>
<td>Product stabilizer and / or winterizing agent</td>
</tr>
<tr>
<td></td>
<td>Methanol</td>
<td>000067-56-1</td>
<td>Product stabilizer and / or winterizing agent</td>
</tr>
<tr>
<td></td>
<td>Formic Acid</td>
<td>000064-18-6</td>
<td>Prevents the corrosion of the pipe</td>
</tr>
<tr>
<td></td>
<td>Acetaldehyde</td>
<td>000075-07-0</td>
<td>Prevents the corrosion of the pipe</td>
</tr>
<tr>
<td>Crosslinker</td>
<td>Petroleum Distillate</td>
<td>064741-85-1</td>
<td>Carrier fluid for borate or zirconate crosslinker</td>
</tr>
<tr>
<td></td>
<td>Hydrotreated Light Petroleum Distillate</td>
<td>064742-47-8</td>
<td>Carrier fluid for borate or zirconate crosslinker</td>
</tr>
<tr>
<td></td>
<td>Potassium Metaborate</td>
<td>013709-94-9</td>
<td>Maintains fluid viscosity as temperature increases</td>
</tr>
<tr>
<td></td>
<td>Triethanolamine Zirconate</td>
<td>101033-44-7</td>
<td>Maintains fluid viscosity as temperature increases</td>
</tr>
<tr>
<td></td>
<td>Sodium Tetraborate</td>
<td>001303-96-4</td>
<td>Maintains fluid viscosity as temperature increases</td>
</tr>
</tbody>
</table>

Ministry of National Infrastructure, Energy and Water Resources, Natural Resources Administration  
E. S. Artom St., POB. 36148, Jerusalem 9136002. Tel: 972-2-5316131, Fax: 972-2-5316147  
Internet Address: [www.energy.gov.il](http://www.energy.gov.il)
## Hydraulic fracturing design and operations guidelines

<table>
<thead>
<tr>
<th>Friction Reducer</th>
<th>Polycrylamide</th>
<th>009003-05-8</th>
<th>“Slicks” the water to minimize friction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Petroleum Distillate</td>
<td>064741-85-1</td>
<td>Carrier fluid for polycrylamide friction reducer</td>
</tr>
<tr>
<td></td>
<td>Hydrotreated Light Petroleum Distillate</td>
<td>064742-47-8</td>
<td>Carrier fluid for polycrylamide friction reducer</td>
</tr>
<tr>
<td></td>
<td>Methanol</td>
<td>000067-56-1</td>
<td>Product stabilizer and / or winterizing agent.</td>
</tr>
<tr>
<td></td>
<td>Ethylene Glycol</td>
<td>000107-21-1</td>
<td>Product stabilizer and / or winterizing agent.</td>
</tr>
<tr>
<td>Gelling Agent</td>
<td>Guar Gum</td>
<td>009000-30-0</td>
<td>Thickens the water in order to suspend the sand</td>
</tr>
<tr>
<td></td>
<td>Petroleum Distillate</td>
<td>064741-85-1</td>
<td>Carrier fluid for guar gum in liquid gels</td>
</tr>
<tr>
<td></td>
<td>Hydrotreated Light Petroleum Distillate</td>
<td>064742-47-8</td>
<td>Carrier fluid for guar gum in liquid gels</td>
</tr>
<tr>
<td></td>
<td>Methanol</td>
<td>000067-56-1</td>
<td>Product stabilizer and / or winterizing agent.</td>
</tr>
<tr>
<td></td>
<td>Polysaccharide Blend</td>
<td>068130-15-4</td>
<td>Thickens the water in order to suspend the sand</td>
</tr>
<tr>
<td></td>
<td>Ethylene Glycol</td>
<td>000107-21-1</td>
<td>Product stabilizer and / or winterizing agent.</td>
</tr>
<tr>
<td>Iron Control</td>
<td>Citric Acid</td>
<td>000077-92-9</td>
<td>Prevents precipitation of metal oxides</td>
</tr>
<tr>
<td></td>
<td>Acetic Acid</td>
<td>000064-19-7</td>
<td>Prevents precipitation of metal oxides</td>
</tr>
<tr>
<td></td>
<td>Thioglycolic Acid</td>
<td>000068-11-1</td>
<td>Prevents precipitation of metal oxides</td>
</tr>
<tr>
<td></td>
<td>Sodium Erythorbate</td>
<td>006381-77-7</td>
<td>Prevents precipitation of metal oxides</td>
</tr>
<tr>
<td>Non-Emulsifier</td>
<td>Lauryl Sulphate</td>
<td>000151-21-3</td>
<td>Used to prevent the formation of emulsions in the fracture fluid</td>
</tr>
<tr>
<td></td>
<td>Isopropanol</td>
<td>000067-63-0</td>
<td>Product stabilizer and / or winterizing agent.</td>
</tr>
<tr>
<td></td>
<td>Ethylene Glycol</td>
<td>000107-21-1</td>
<td>Product stabilizer and / or winterizing agent.</td>
</tr>
<tr>
<td>pH Adjusting Agent</td>
<td>Sodium Hydroxide</td>
<td>001310-73-2</td>
<td>Adjusts the pH of fluid to maintain the effectiveness of other components, such as crosslinkers</td>
</tr>
<tr>
<td>-------------------</td>
<td>------------------</td>
<td>-------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Potassium Hydroxide</td>
<td>001310-58-3</td>
<td>Adjusts the pH of fluid to maintain the effectiveness of other components, such as crosslinkers</td>
</tr>
<tr>
<td></td>
<td>Acetic Acid</td>
<td>000064-19-7</td>
<td>Adjusts the pH of fluid to maintain the effectiveness of other components, such as crosslinkers</td>
</tr>
<tr>
<td></td>
<td>Sodium Carbonate</td>
<td>00497-19-8</td>
<td>Adjusts the pH of fluid to maintain the effectiveness of other components, such as crosslinkers</td>
</tr>
<tr>
<td></td>
<td>Potassium Carbonate</td>
<td>00584-08-7</td>
<td>Adjusts the pH of fluid to maintain the effectiveness of other components, such as crosslinkers</td>
</tr>
<tr>
<td>Scale Inhibitor</td>
<td>Copolymer of Acrylamide and Sodium Acrylate</td>
<td>025987-30-8</td>
<td>Prevents scale deposits in the pipe</td>
</tr>
<tr>
<td></td>
<td>Sodium Polycarboxylate</td>
<td>N/A</td>
<td>Prevents scale deposits in the pipe</td>
</tr>
<tr>
<td></td>
<td>Phosphonic Acid Salt</td>
<td>N/A</td>
<td>Prevents scale deposits in the pipe</td>
</tr>
<tr>
<td>Surfactant</td>
<td>Lauryl Sulphate</td>
<td>000151-21-3</td>
<td>Used to increase the viscosity of the fracture fluid</td>
</tr>
<tr>
<td></td>
<td>Ethanol</td>
<td>000064-17-5</td>
<td>Product stabilizer and / or winterizing agent.</td>
</tr>
<tr>
<td></td>
<td>Naphthalene</td>
<td>000091-20-3</td>
<td>Carrier fluid for the active surfactant ingredients</td>
</tr>
<tr>
<td></td>
<td>Methanol</td>
<td>000067-56-1</td>
<td>Product stabilizer and / or winterizing agent.</td>
</tr>
<tr>
<td></td>
<td>Isopropyl Alcohol</td>
<td>000067-63-0</td>
<td>Product stabilizer and / or winterizing agent.</td>
</tr>
<tr>
<td></td>
<td>2-Butoxyethanol</td>
<td>000111-76-2</td>
<td>Product stabilizer</td>
</tr>
</tbody>
</table>
Appendix 3 – API Standards supporting HF