Modeling Near Wellbore Leakage Pathways in Shale Gas Wells: Investigating Short and Long Terms Wellbore Integrity

S.Salehi

Petroleum Engineering Department, University of Louisiana at Lafayette

Introduction

Well construction practices are very critical affecting short and long terms wellbore integrity. A well can keep its integrity in short term, however, it can lose its integrity in log term due to different materials degradation, change in stresses because of depletion and/or cyclic pressure and thermal loads. The followings are the main aspects that need to be addressed:

1. Short and Long terms well integrity: What are the potential leakages in the near-wellbore regarding all possible scenarios?
2. How efficient are the current well construction procedures (standards) to prevent gas migration to the surface drinking water resources in short and long term?
3. How to identify the wells with construction problems that have been already drilled/or abandoned in the past? And what kind of intervention/remediation they will require?
4. Wellbore integrity in injection wells (for waste water disposal), re-fracturing occasions and deep gas wells: How the injection, thermal loads and re-fracturing will affect short and long terms well integrity?

Possible Leakage Pathways in Near Wellbore

Generally a wellbore can fail due to several reasons such as poor cementing operation and/or failures due to mechanical and thermal loads. These loads can create tensile and shear failures in boundaries of the casing-cement-formation or inside each of these elements. Changing fluids density for completion and stimulation can also induce mechanical loads inside well which need to be considered for integrity evaluation. Changes in temperature due to cooling or heating can impose thermal stresses which may trigger long term well integrity. Furthermore corrosion in the casing or chemical reactions of the cement can also create near wellbore leakage paths (Figure 1)

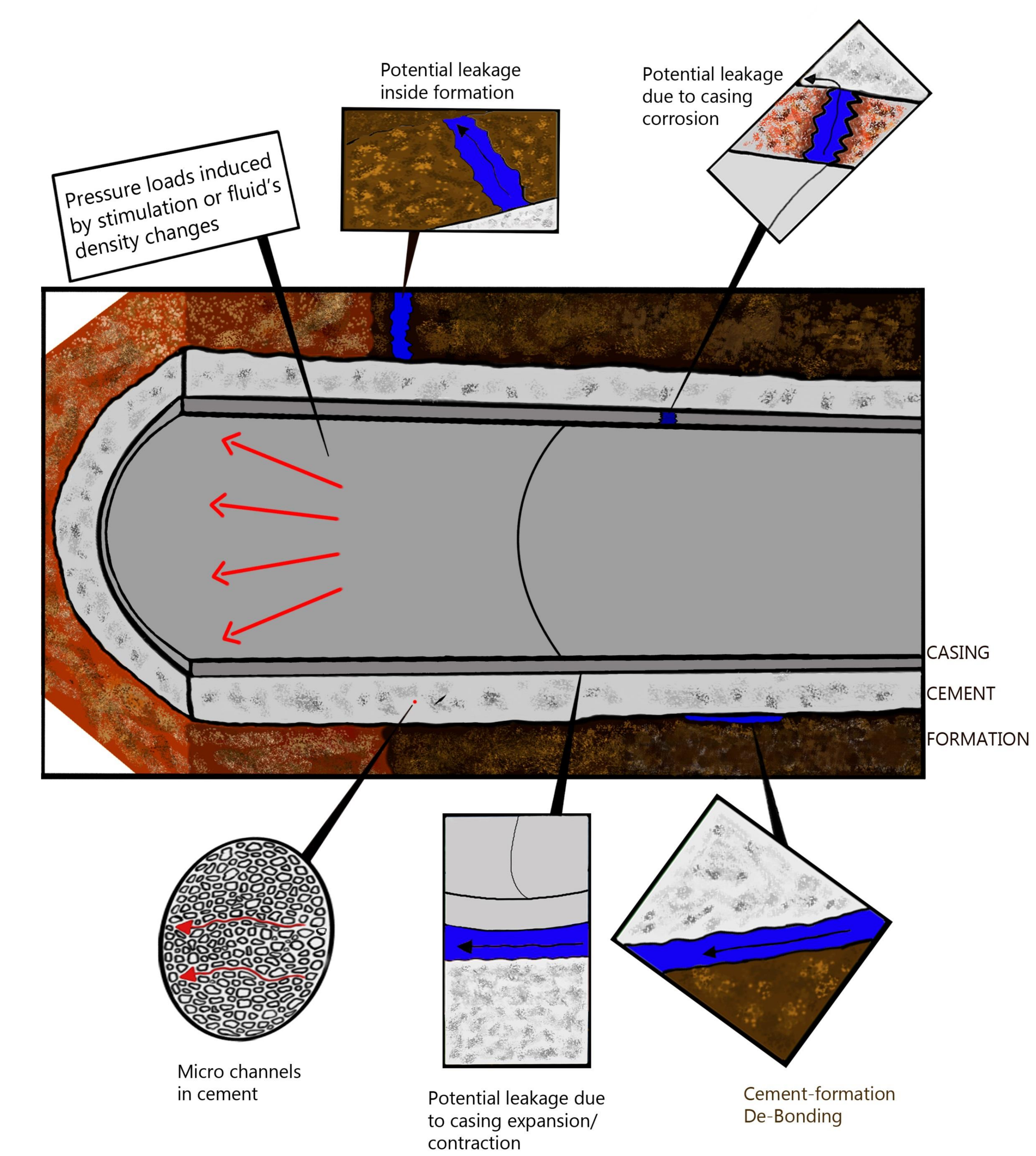


Figure 1. Potential leakage pathways created in near wellbore due to poor cement job or failure initiated by additional loads induced through the well's life such as stimulation or change in the pressure inside the wellbore as well as possible thermal loads

Pre-completion, Completion, Production , Post-production and Abandoned Wellbore Integrity Aspects

- Insufficient mud removal
- Cement hydration and shrinkage
- Micro-channels in cement
- Casing centralization

- Cyclic pressure and thermal loads
- Casing corrosion and degradation
- Casing-cement-formation de-bonding

- Depletion
- Re-fracturing
- Abandonment (P&A)

Overview of Major Steps

An integrated numerical/experimental study has been initiated to investigate the near wellbore leakage pathways in shale gas wells. The main objective of study is to explore various leakage scenarios in which well integrity can be compromised. Laboratory experiments are also designed to extract rock and cement properties such as Young's Modulus, UCS, Poisson's ratio, permeability, hydration and heat transfer related properties (Figure 2)

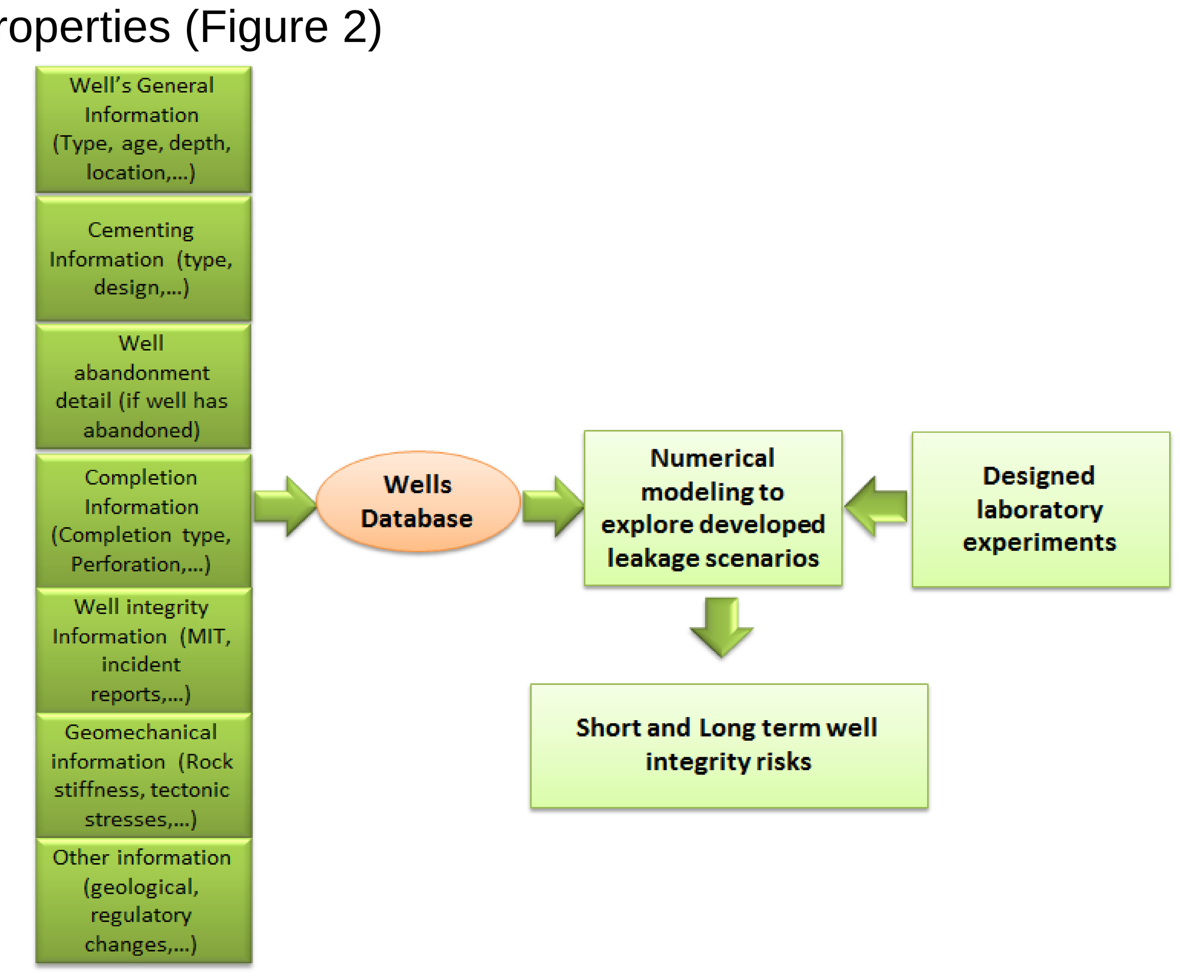
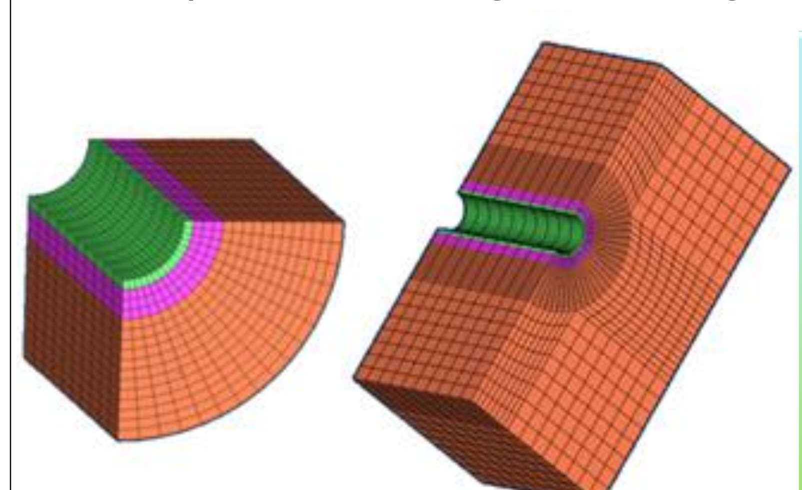


Figure 2. A comprehensive database of wells with inputs form designed lab experiments are currently under construction

Multi Stage Simulations Approach

Three dimensional staged finite-element models are used in this work to include all the steps involved in the well life's cycle. This will allow to analyze previous deformation and loading history applied while drilling, completion and hydraulic fracturing. The numerical models will be used to explore different leakage scenarios developed considering all the stages.



Simulation Stages

- Drilling
- Casing Run and Cementing
- Cement Shrinkage
- Completion and Stimulation
- Possible re-fracturing and final Abandonment

Figure 3. Multi-stage simulations are performed via advanced Finite-element Analysis

Preliminary Results of a Case Study in Haynesville Shale

Drilling and completing wells in Haynesville shale play is associated with very high pressure and temperature downhole environments. The depth of the well (TVD) can range from 10000 to 14000 ft range with temperature exceeding 350 F with common CO_2 influxes [1].

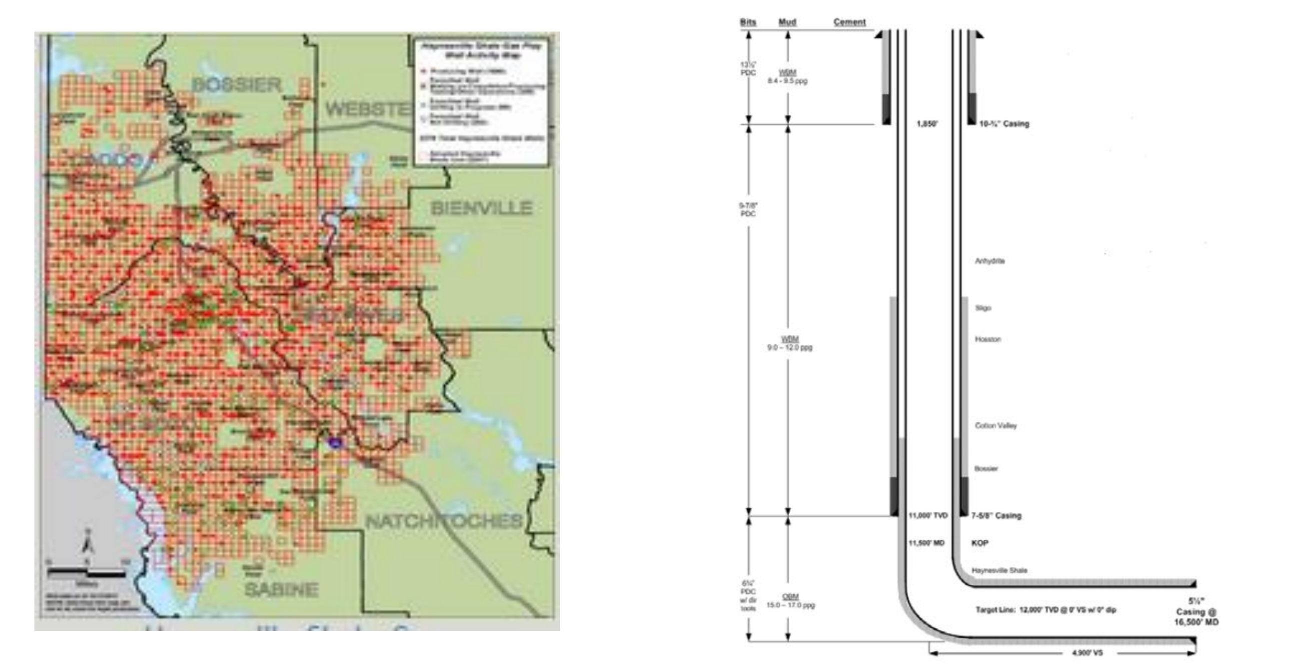


Figure 4. Haynesville Shale Wells Map (left [2]), a typical well design in Haynesville Shale (right, [3])

A recently drilled and completed well was selected in this field to investigate potential short and long term wellbore integrity risks. The well TVD is around 11200 ft depth with approximately 3000 ft lateral section. All the available Mechanical Integrity Tests including pressure tests, CBL/SBL and other petrophysical logs were analyzed for evaluating wellbore integrity and were feed as an inputs in numerical models (Figure 4).

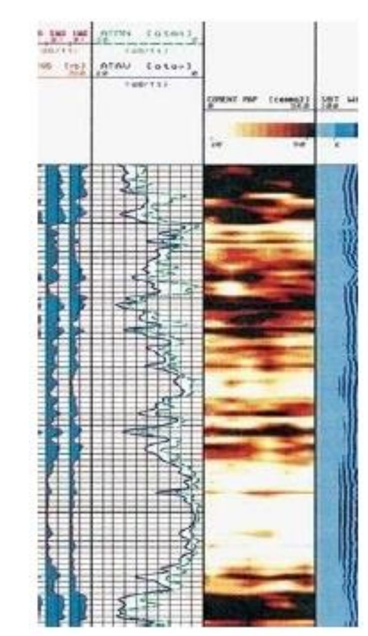


Figure 5- Available mechanical integrity tests for this well were analyzed to detect potential weak zones

Simulations were also carried out for this well regarding integrity risks after the well completed and one possible re-fracturing scenario in future. All stages of drilling, casing, cementing, completion and stimulation were accomplished with evaluating wellbore integrity at each step. Simulations results indicate risk of de-bonding and generation of tensile fractures due to possible mechanical loads induced by re-fracturing loads. The Figure 6 shows the results after well completion (left) where no serious integrity risk is imposed, however, the simulation results after re-fracturing (right) shows potential leakage paths.

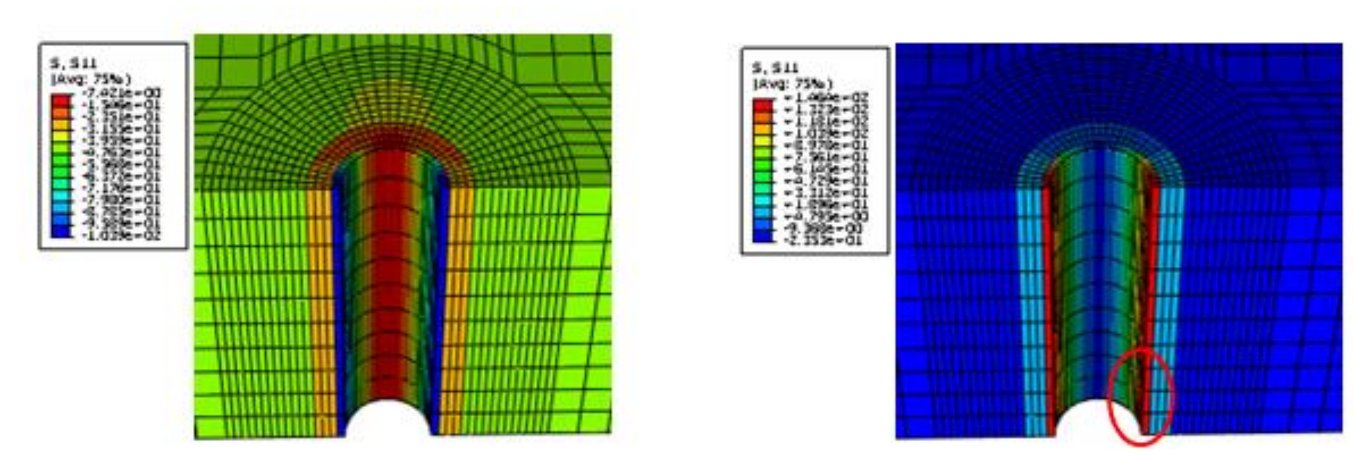


Figure 6. Near well bore modeling after well completion & fracturing (left) and after potential re-fracturing event in the future (right), circle red line shows the failure zone predicted from models

References

[1] Deville et al., 2011, Development of Water-Based Drilling Fluids Customized for Shale Reservoirs, SPE Drilling& Completion

[2] Louisiana Department of Natural Resources (DNR) ,2013.

[3] Webster, J. , Haynesville Shale Drilling, AADE (American Association of Drilling Engineers)