

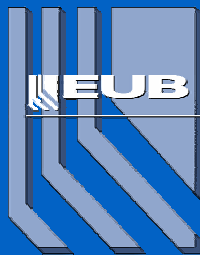
Factors Affecting or Indicating Potential Wellbore Leakage

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Alberta Energy and Utilities Board

Alberta Geological Survey
AGS



Old Wells or New Wells?

Should we worry more about the integrity of future CO₂ injection wells, or about the existing and future wells drilled for purposes other than CO₂ injection?

Deep Wells Drilled in Alberta



End of 2004

- 316,439 total
- 108,706 abandoned

End of 2006

- 362,265 total
- 116,550 abandoned

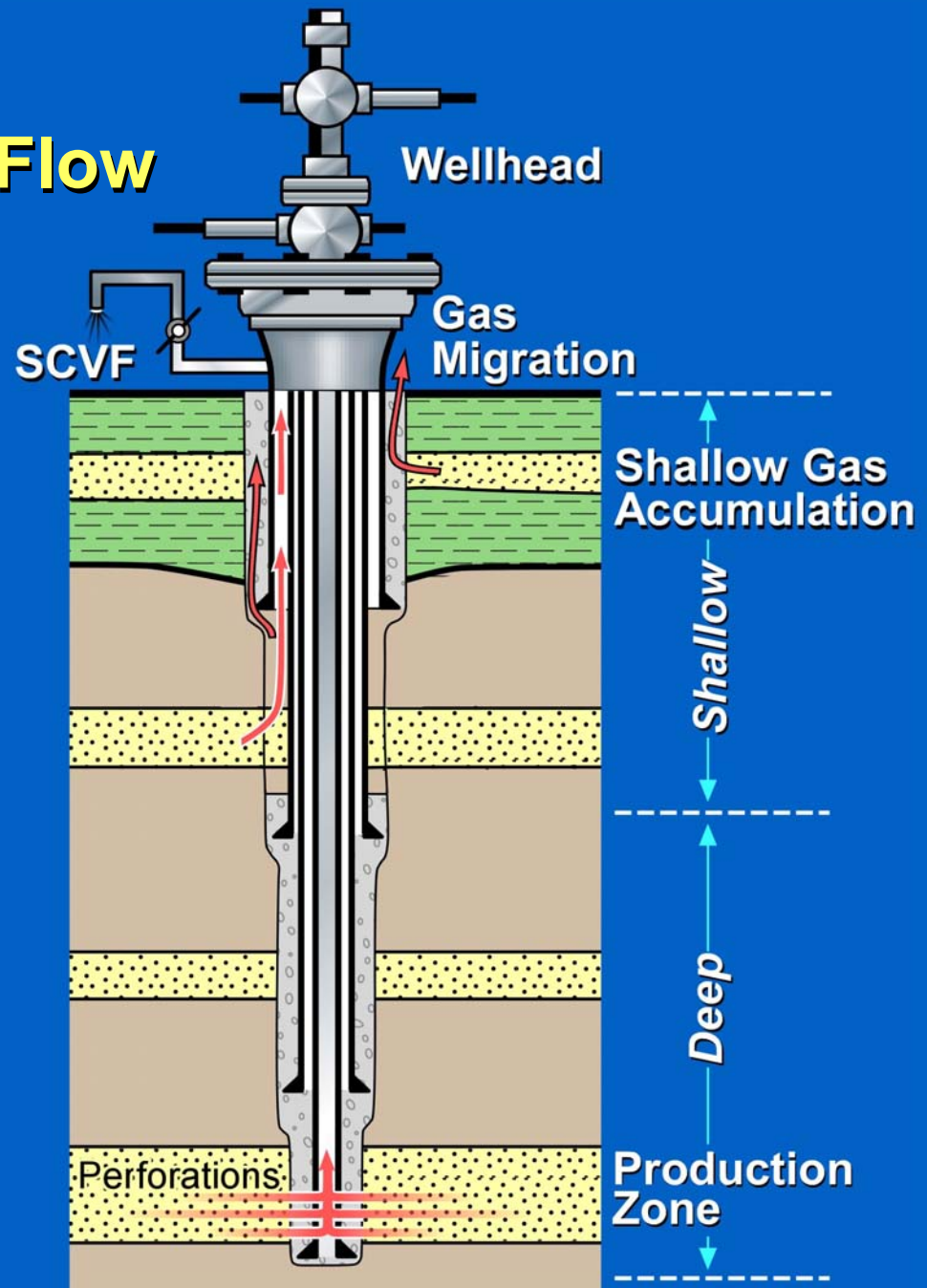
Oldest: 1893

Area: 664,332 km²
(256,610 sq.mi)

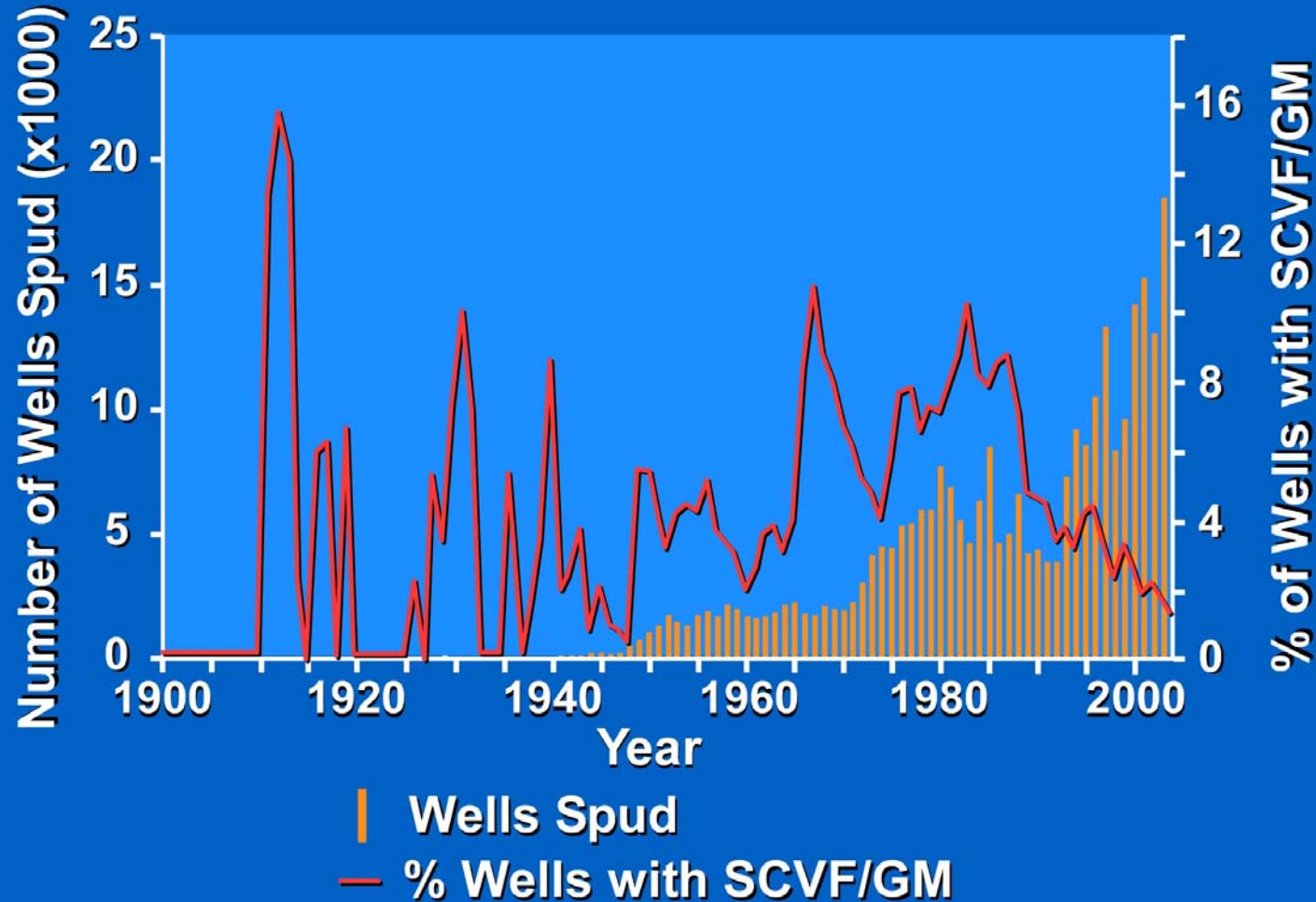
Conditions for Well Leakage Occurrence

- **Leak source**
- **Driving force (head differential, buoyancy)**
- **Leakage pathway**
 - **Poorly cemented casing/hole annulus**
 - **Casing failure**
 - **Abandonment failure**

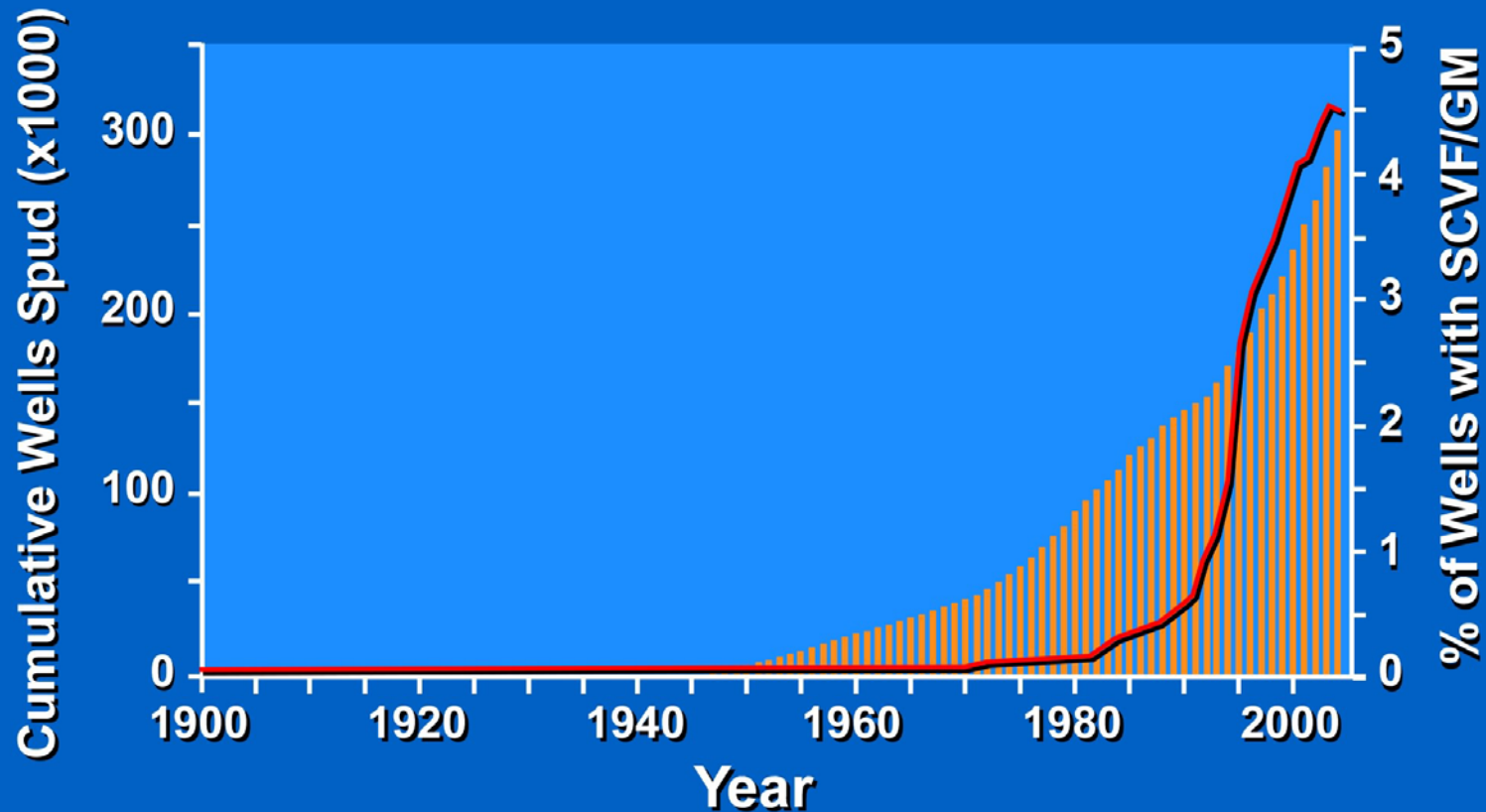
Surface Casing Vent Flow and Gas Migration Flow Pathways in a Well



Wells with SCVF/GM Compared with Wells Drilled - Annual Basis -



Wells with SCVF/GM Compared with Wells Drilled - Cumulative -



-  Cumulative Wells Spud
-  % of Cumulative Wells with SCVF/GM

Example of SCVF and GM Testing



1 Testing for SCVF

2 Testing for GM

Abandoned Well Leaking Brine and Gas near Peace River, Alberta



Gas Bubbling at the Cap Welding of the Surface Casing



Gas Bubbling at the Cap Welding of the Production Casing



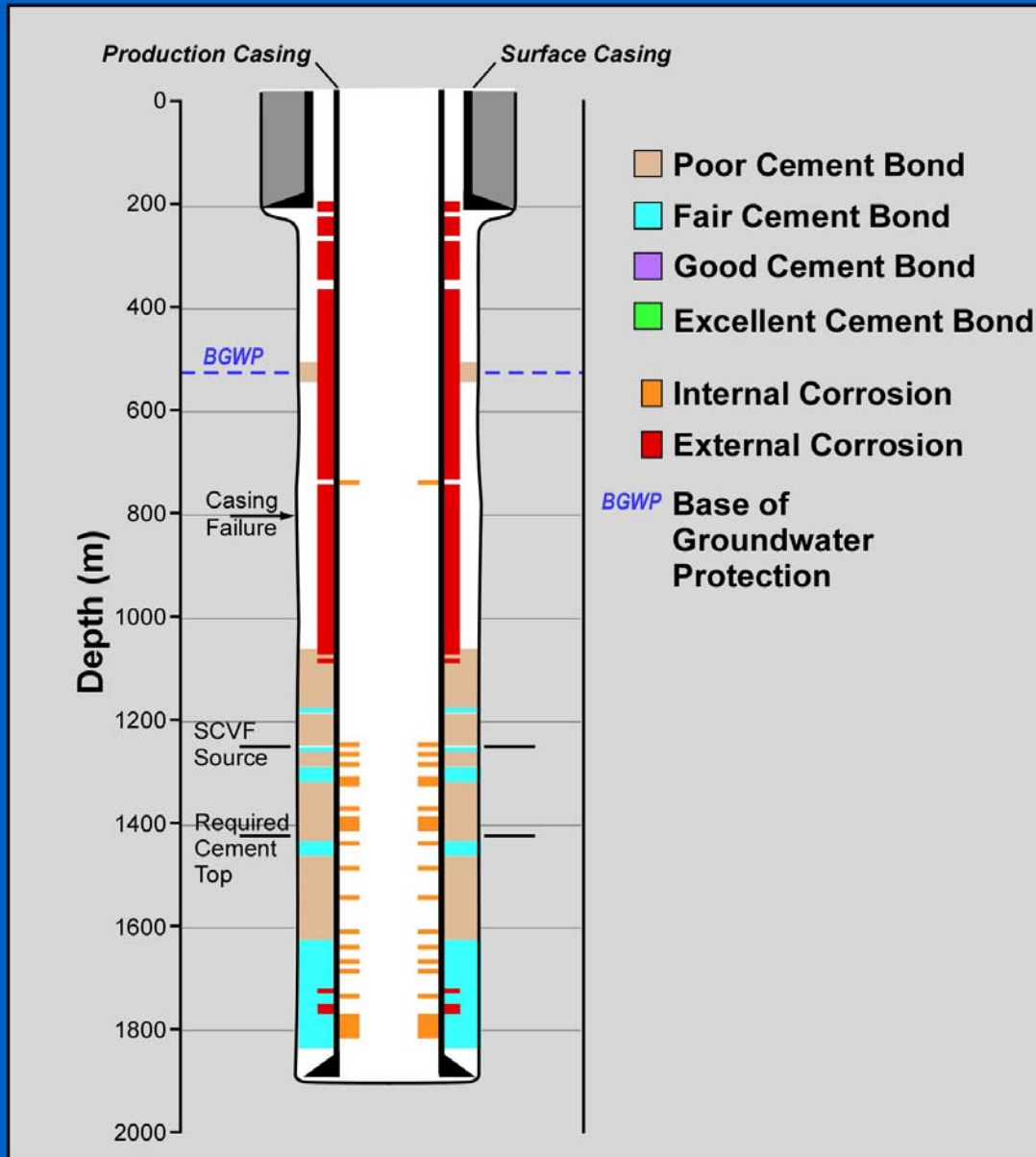
Analysis of Factors Affecting Well Leakage

- **Data mining**
 - **EUB's public databases on wells and production**
 - **EUB's databases on SCVF, GM, casing failure and non-routine well abandonment**

- **Historical documents and regulatory changes**

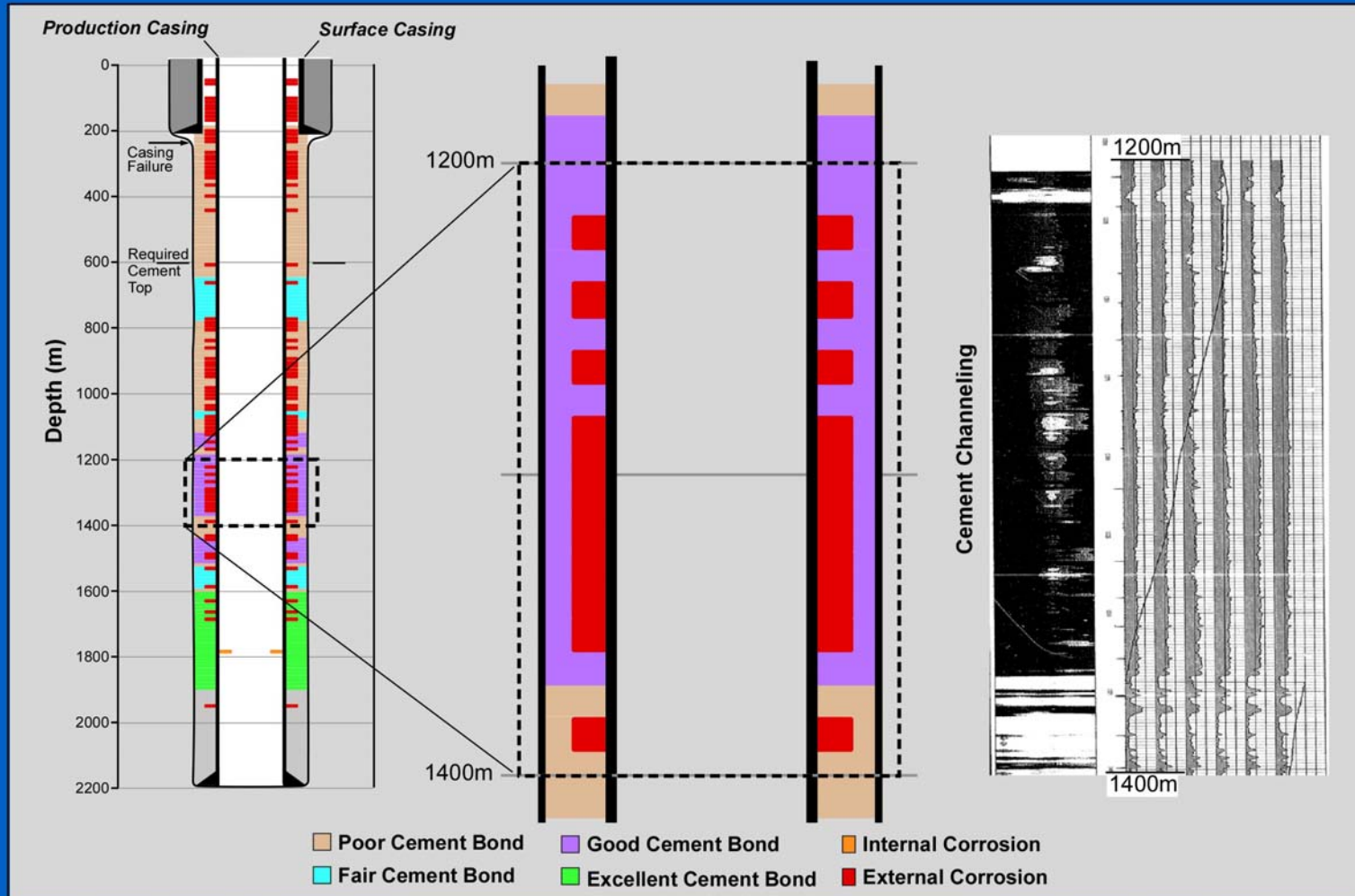
- **Casing inspection logs and cement logs for ~500 wells, of which 142 had adequate data for full evaluation**

- **Depth of groundwater protection**



Example of Cement and Casing Quality in a Well in the Haynes Field, Alberta

Example of Well Log Analysis Showing Corrosion Due to Cement Channeling



Factors of No Apparent Impact

- **Well age**
- **Well operational mode: production, injection or disposal**
- **Completion interval**
- **Presence of H₂S and/or CO₂**

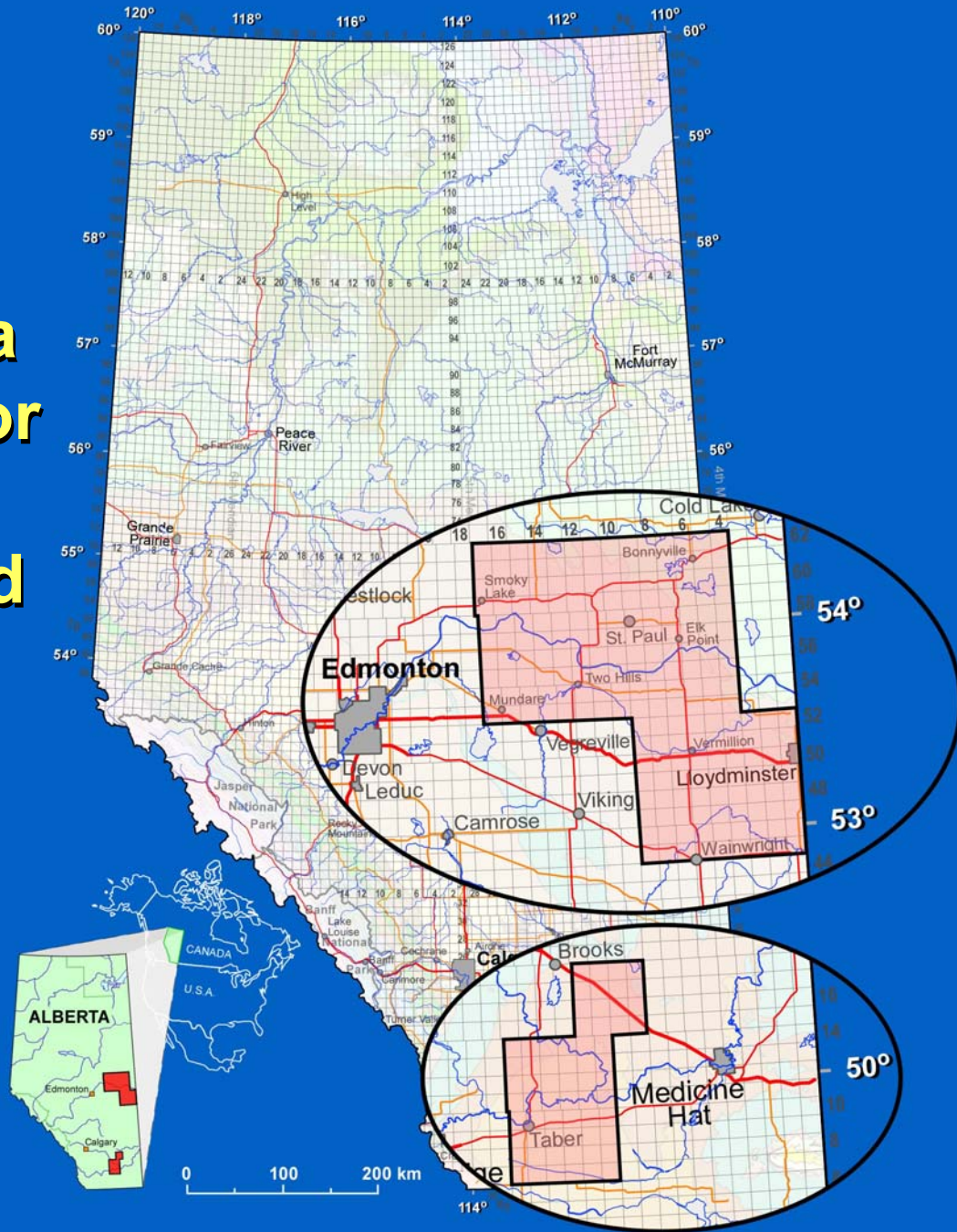
Factors of Minor Impact

- **Licensee**
- **Depth of surface casing**
- **Total depth**
- **Well density**
- **Topography**

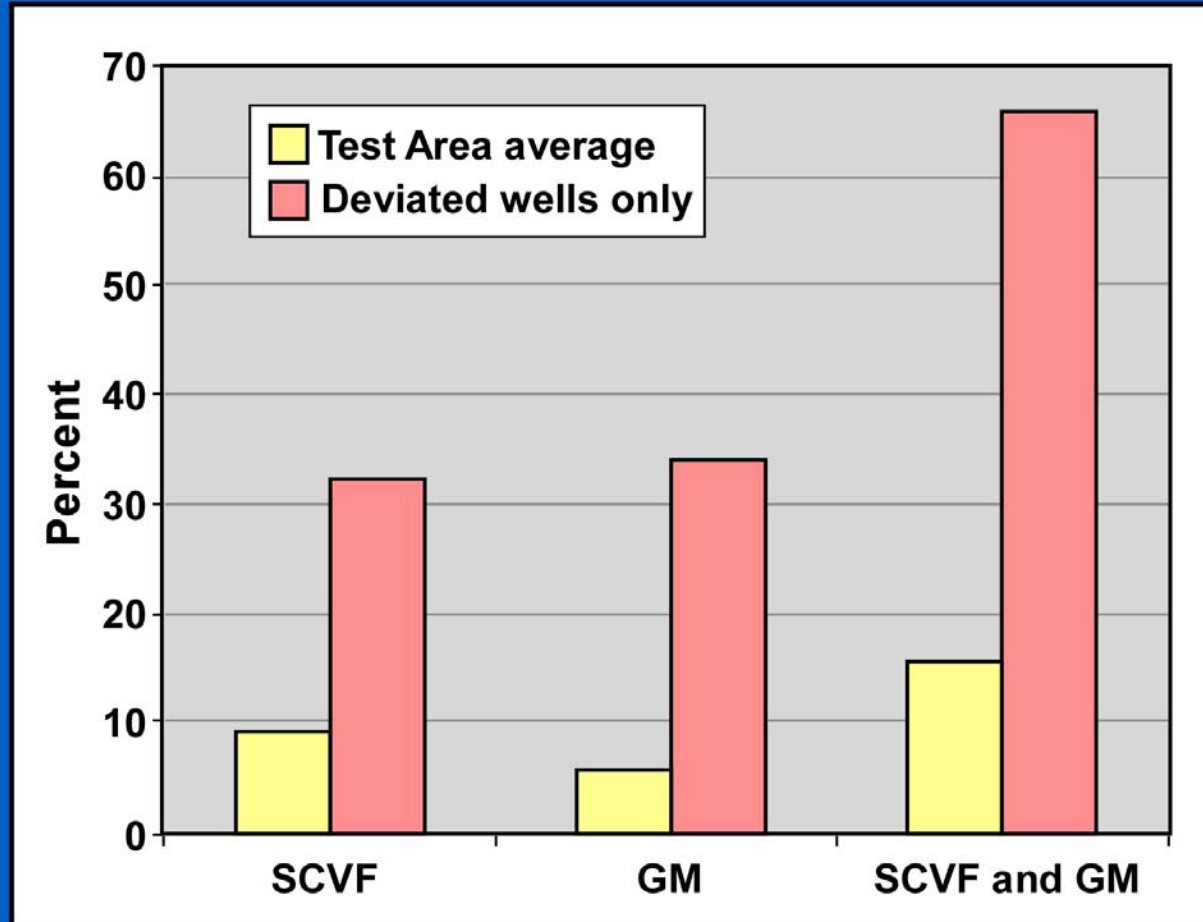
Factors of Major Impact

- **Geographic area (Test Area)**
- **Well deviation**
- **Well type:**
 - drilled and abandoned (SCVF/GM incidence rate of 0.5%)
 - cased and abandoned (SCVF/GM incidence rate of 14%), for 98% of the total
- **Abandonment method (bridge plugs, welded caps)**
- **Economic activity, regulatory changes and SCVF/GM testing**
- **Uncemented casing/hole annulus!**

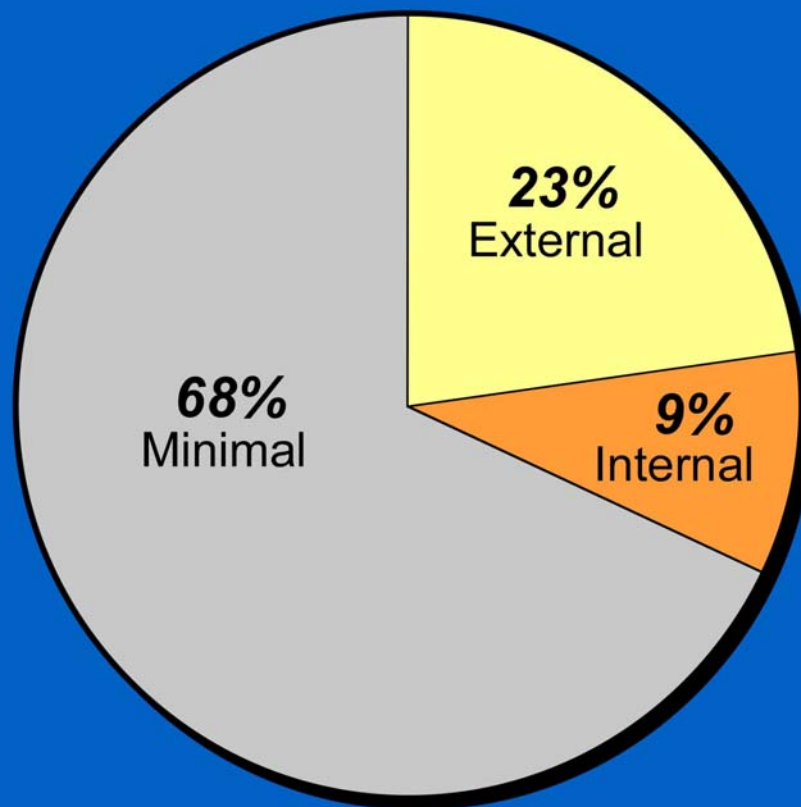
Areas in Alberta where Testing for Gas Migration was/is Required



Occurrence of SCVF/GM in the Test Area, Alberta

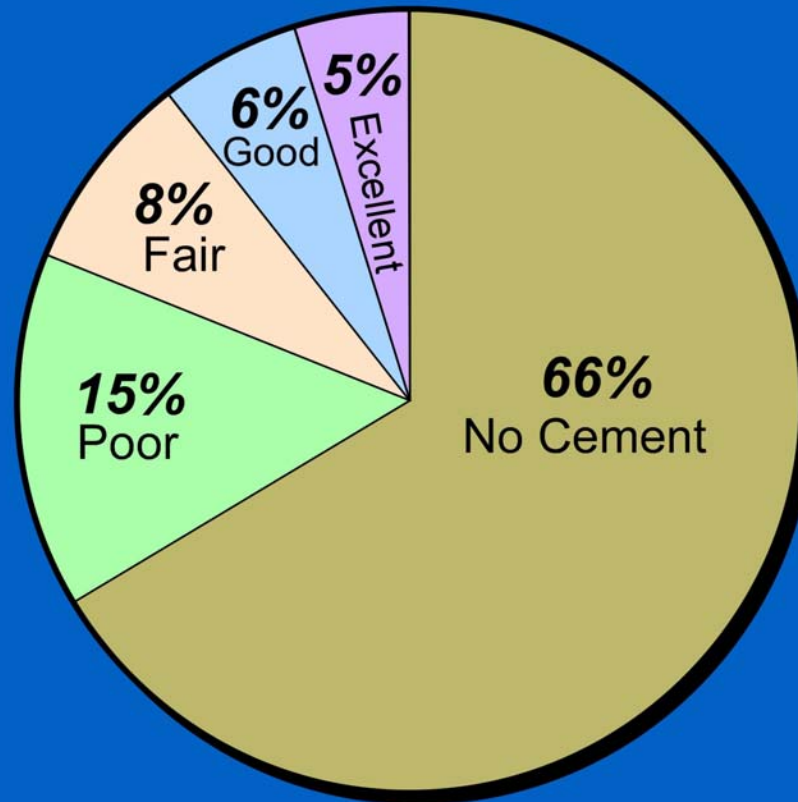


Corrosion Location



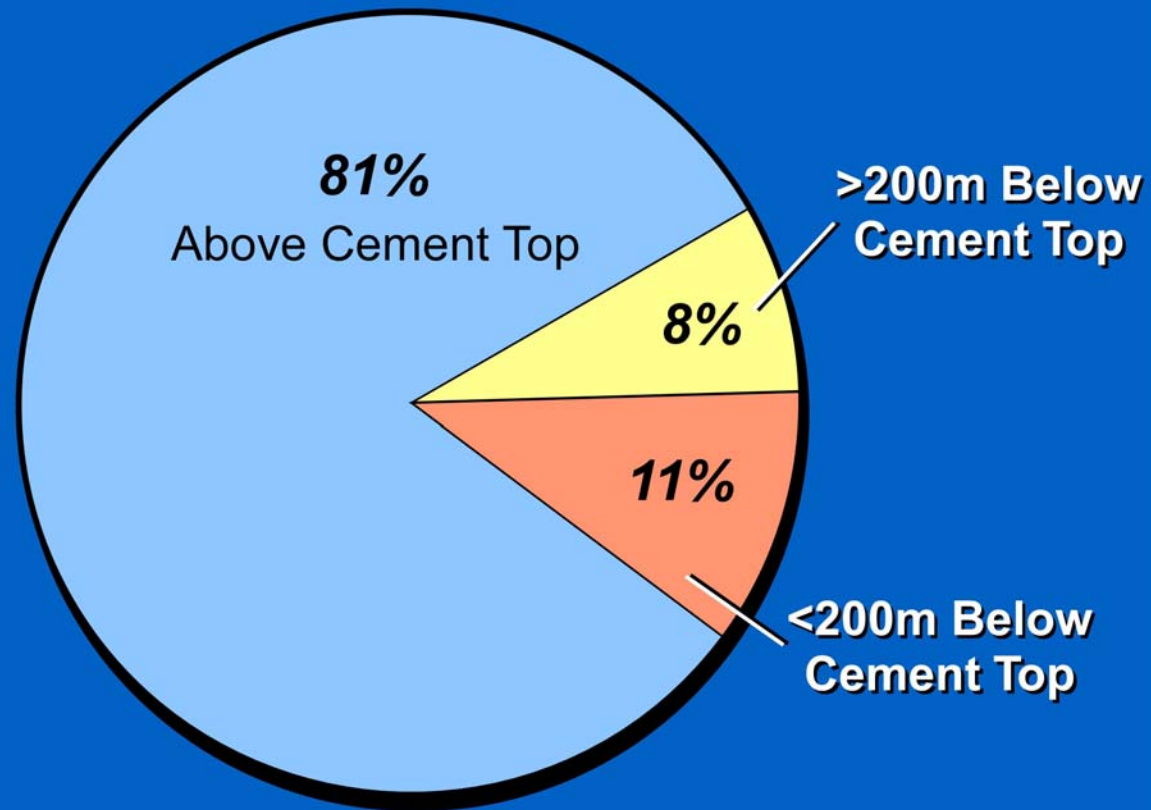
129,773 m logged in 142 wells

External Corrosion versus Cement Quality



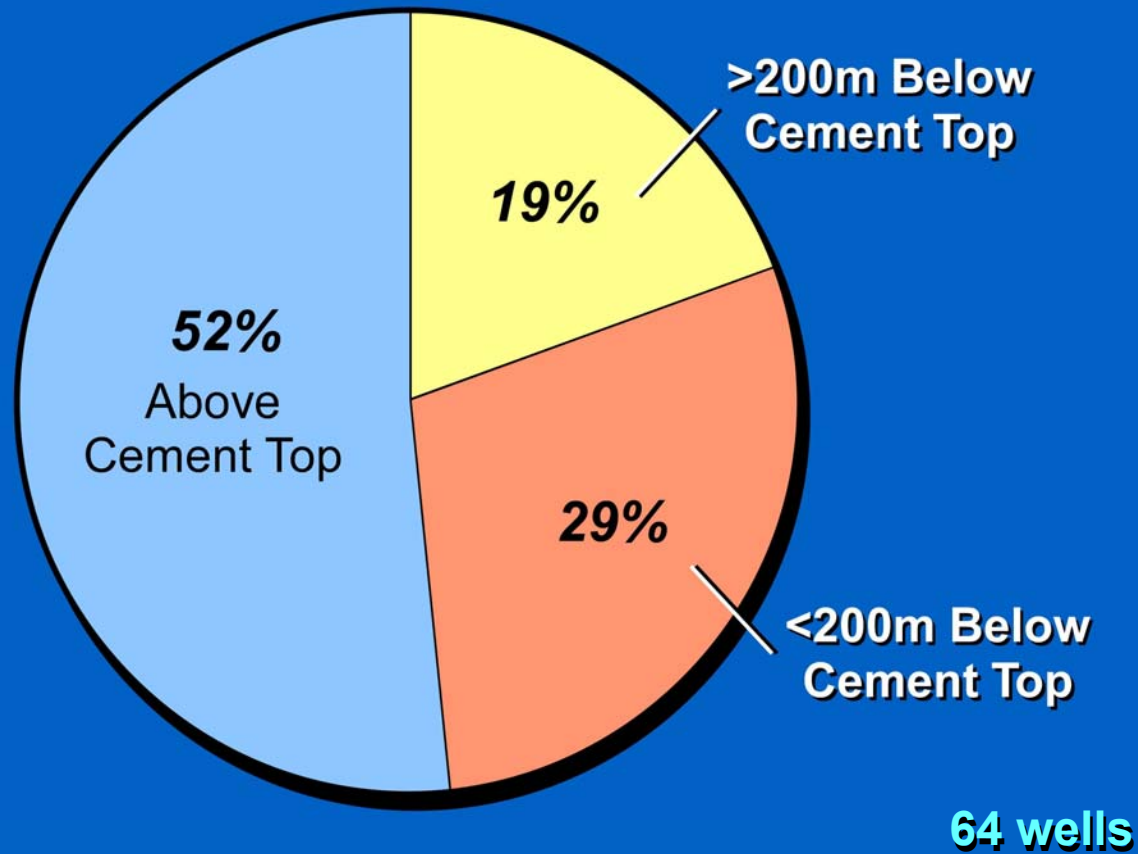
10,442 m logged in 142 wells

Location of SCVF/GM Source versus Cement Top

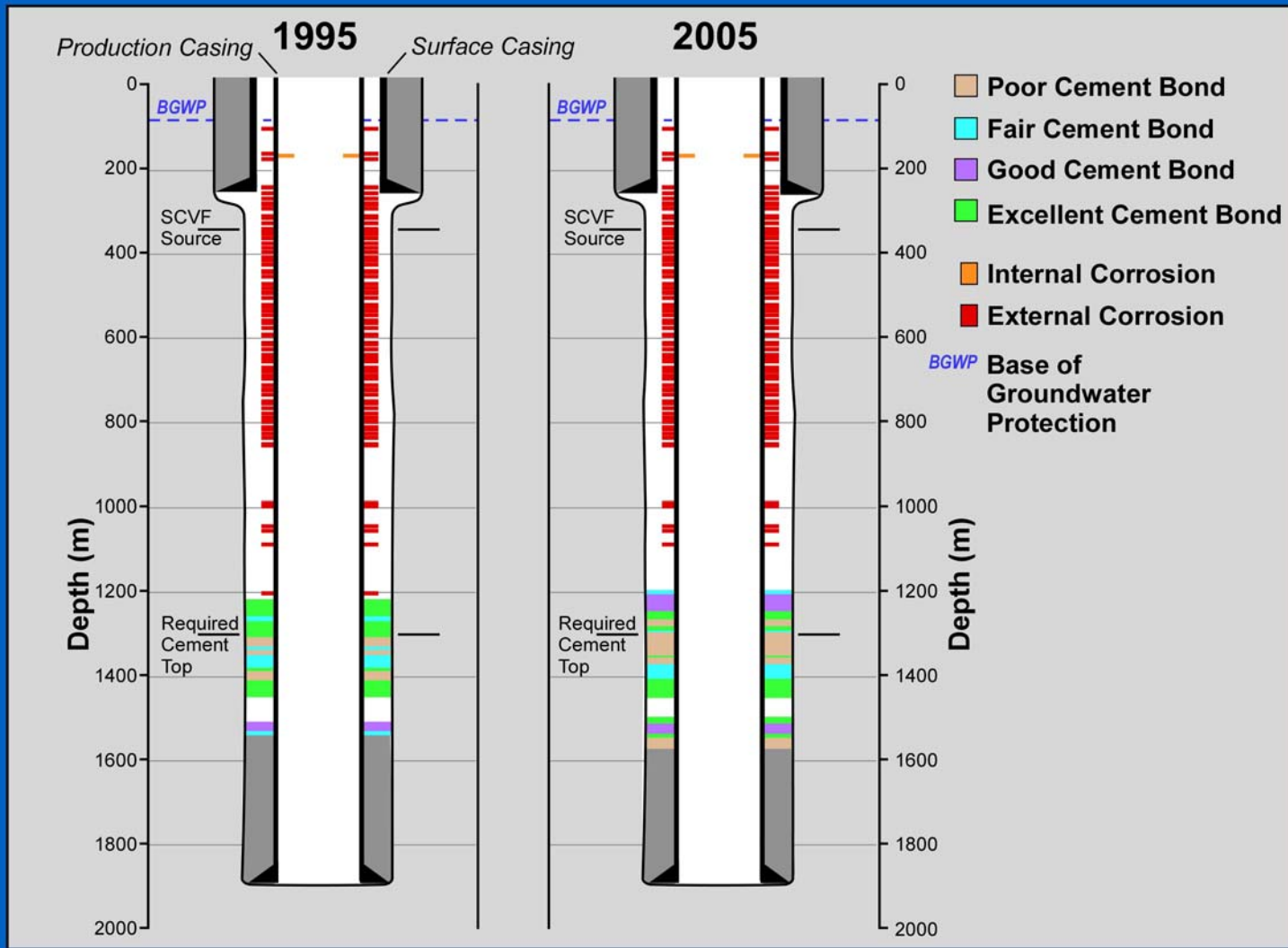


64 wells

Location of Casing Failure versus Cement Top



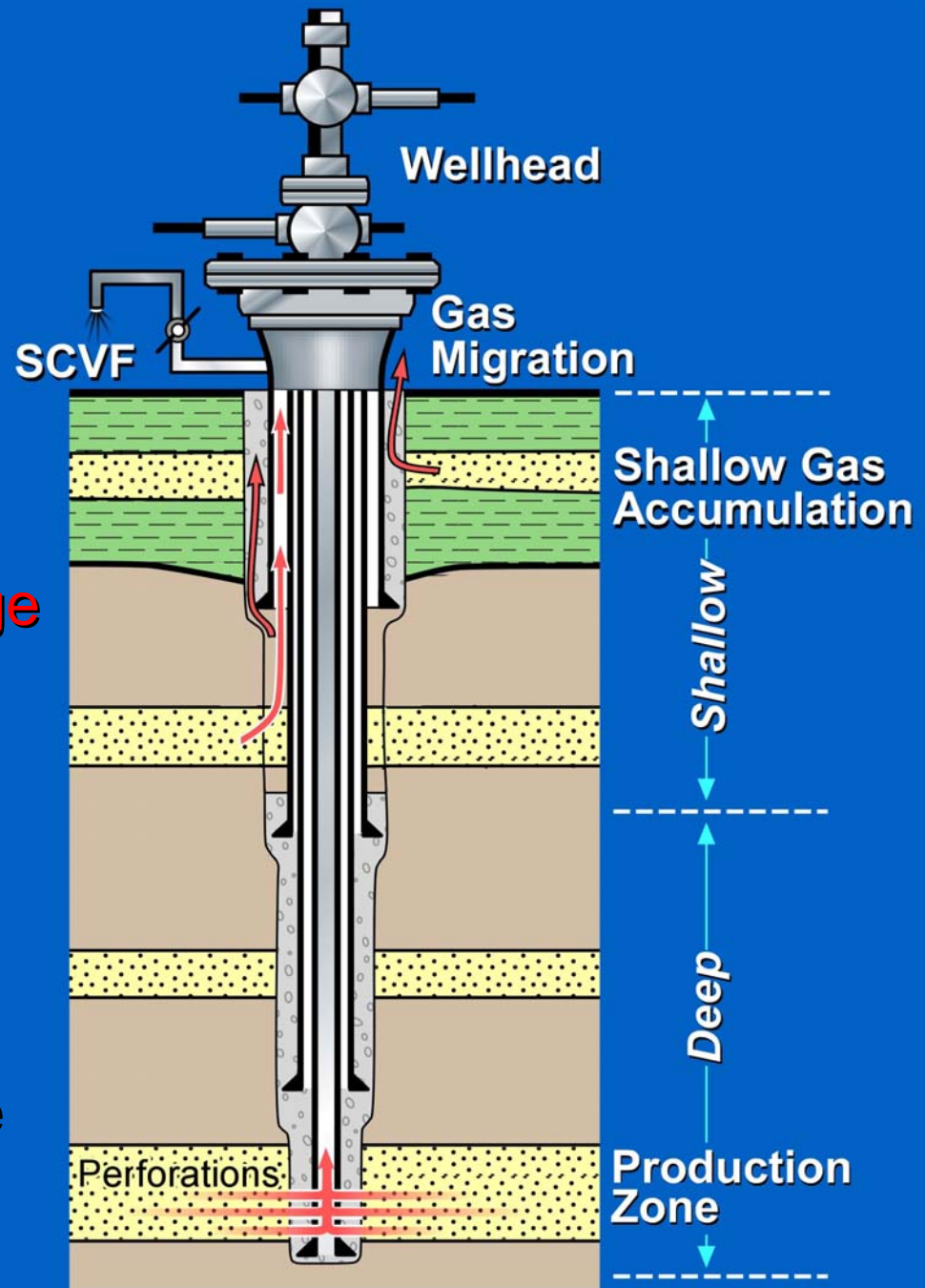
Interpretation of Cement Bond Logs in the Same Well in the Zama Field



Leakage Potential along a Well

Shallower, upper part
Higher potential for leakage

Deep, lower part
completed in
producing zones
Less potential for leakage

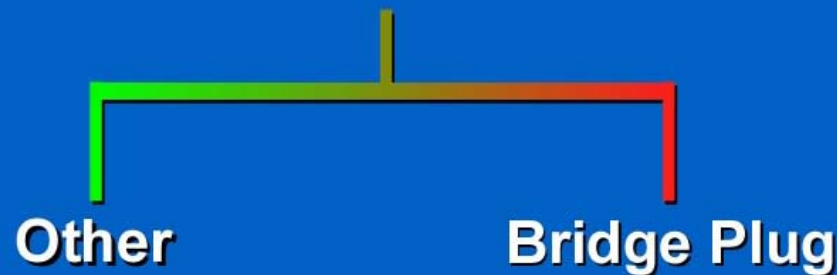


Well Attributes for Leakage Assessment in Alberta

- **Type: drilled and abandoned, or cased**
- **Cementing requirements and practices**
- **Location (in Test Area or outside)**
- **Direction: vertical or deviated (including horizontal)**
- **Time of drilling in relation to economic activity and regulatory changes**
- **Time of abandonment in relation to regulatory changes**

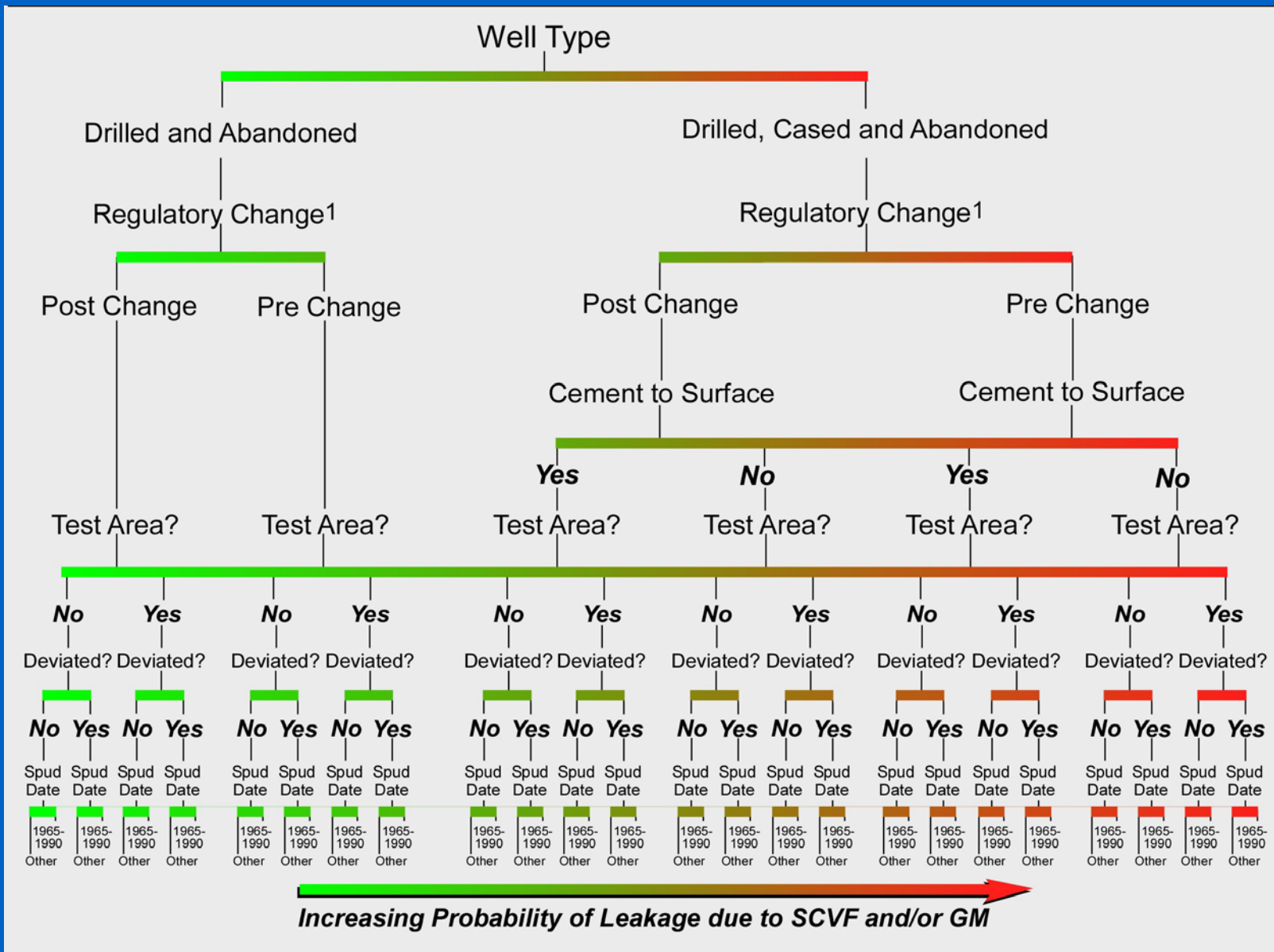
Potential for Well Leakage Inside Production Casing

Abandonment Type



*Increasing Probability of Leakage
Inside the Casing*

Assessment of the Potential for Well Leakage



Conclusions

- **The majority of well leakage is due to time-independent mechanical factors controlled during well drilling, construction or abandonment, mainly cementing**
- **Uncemented casing is the main factor in SCVF/GM and/or casing failure occurrence**
- **Good quality cementing will likely protect wells against cement degradation and casing corrosion**
- **The deep portion of wells is usually well cemented and zonally isolated**
- **Good and properly-enforced regulations are key in controlling and detecting well leakage**

Answer to Question on the First Slide

It is not the CO₂ injection wells that may/will pose a risk, they will be properly constructed and monitored, and, relatively speaking won't be too many.

It is the existing wells that will pose the greater risk!

Bachu and Watson – Possible Indicators for CO₂ Leakage along Wells, GHGT-8, 2006
Watson and Bachu - Factors Affecting or Indicating Potential Wellbore Leakage;
SPE Paper 106817, 2007