

Human Factors and Risk Informed Decision Support for Underground Gas Storage

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Lessons learned across industries: “Macondo was the offshore industry’s Three Mile Island”

- Continued occurrence and recurrence of major accidents across many industries



- Effective decision support is needed to continuously manage the barriers and success paths for preventing and mitigating major accidents

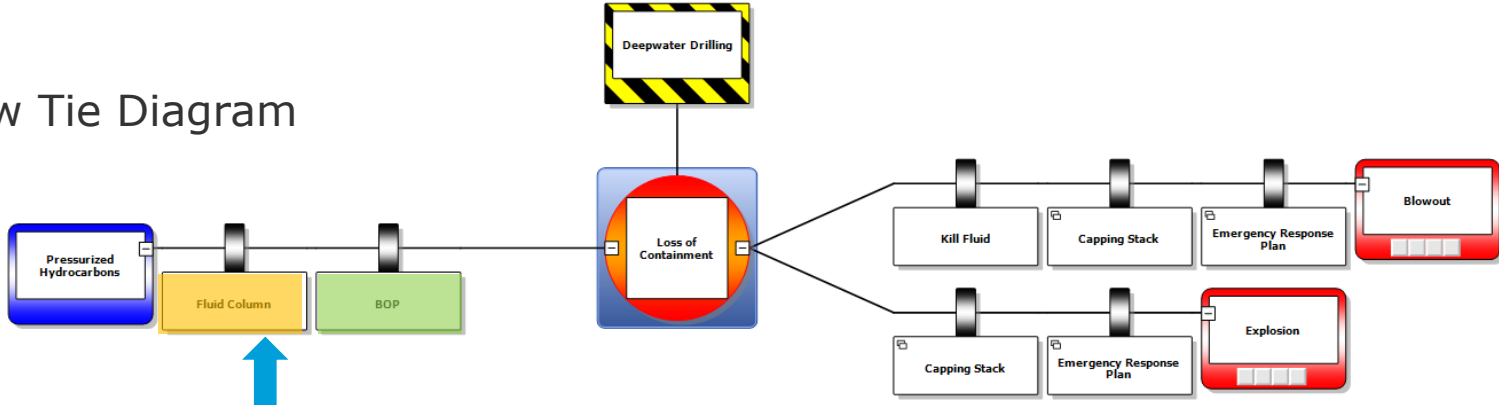
The Dynamic Barrier Management concept for managing well integrity risks for offshore operations and underground gas storage

- Two types of information - (1) the condition of barriers and success paths and (2) practical decision guidance – are needed to effectively manage risks of major accidents.
 - **Barrier:** *Physical or non-physical means to prevent an accident or mitigate its consequences*
 - **Success Path:** *Equipment and processes (human, software, administrative) needed for the barrier to perform its function*
- **Solution** - **Combine barriers and success paths to:**
 - Systematically identify information requirements for continuous barrier and success path management
 - Provide **decision guidance** to restore degraded barriers and implement alternate success paths when needed, providing complementary failure and success perspectives
 - Develop an intuitive, visual “common language” for communication, consensus, and action among:
 - Offshore operators
 - Industry groups
 - Regulatory bodies
 - External stakeholders

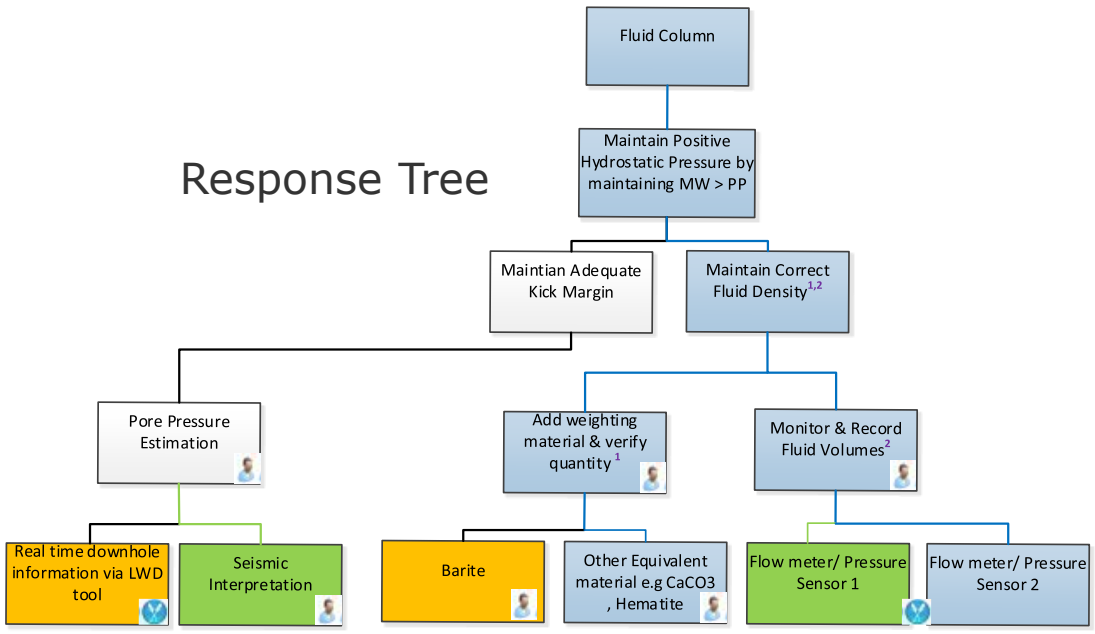
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Bow tie diagrams and response trees form the foundation for decision support for dynamic barrier management

Bow Tie Diagram



Response Tree



Key:

- Recommended Success Path:** Path Name, Priority (Blue box)
- Available Success Paths:** Path Name, Priority (Green box)
- Unavailable Success Paths:** Path Name, Priority (Red box)
- Failed Element:** Failed Element (Yellow box)

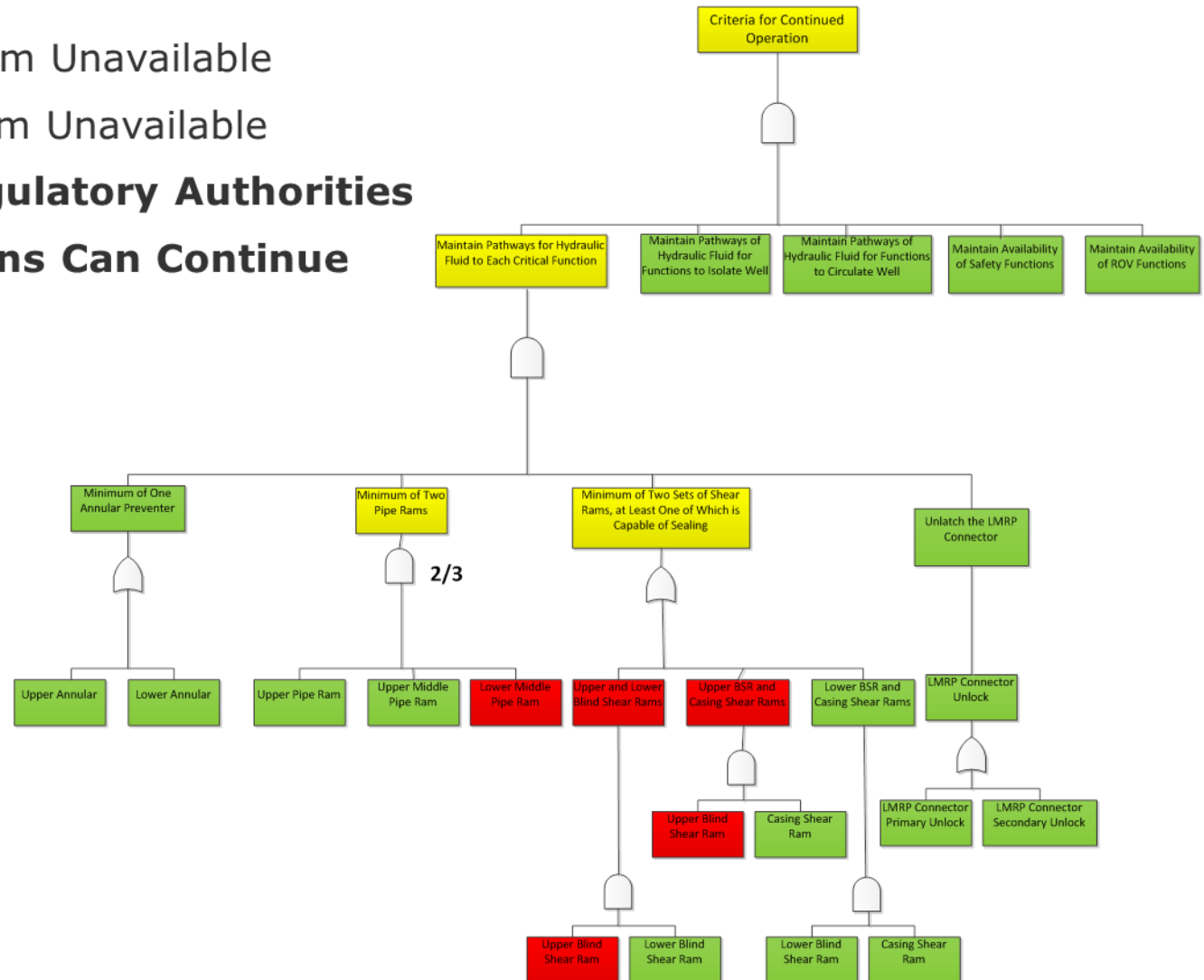
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Regulatory Compliance Assessment During Operations: Decision Criteria for Drilling Operations Based on BOP Functionality

Upper Blind Shear Ram Unavailable

Lower Middle Pipe Ram Unavailable

- **Consult with Regulatory Authorities**
- **Drilling Operations Can Continue**



DNV GL Joint Industry Project: Decision Support for Dynamic Barrier Management

Challenge

- Knowing the continuous status of barriers
- Lack of common risk language for communication
- Lack of practical decision support tools for operations

Benefits

- Continuous knowledge of barrier health
- Real time decision support and risk management
- Common language for communication and consensus among engineering, operations, maintenance, and management

Delivery

- The JIP participants will develop and test:
 - Methods, best practices, data sources, and tools
 - Standardized bow tie diagrams, response trees, and decision protocols
 - Pilot-scale decision support systems

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Contact:

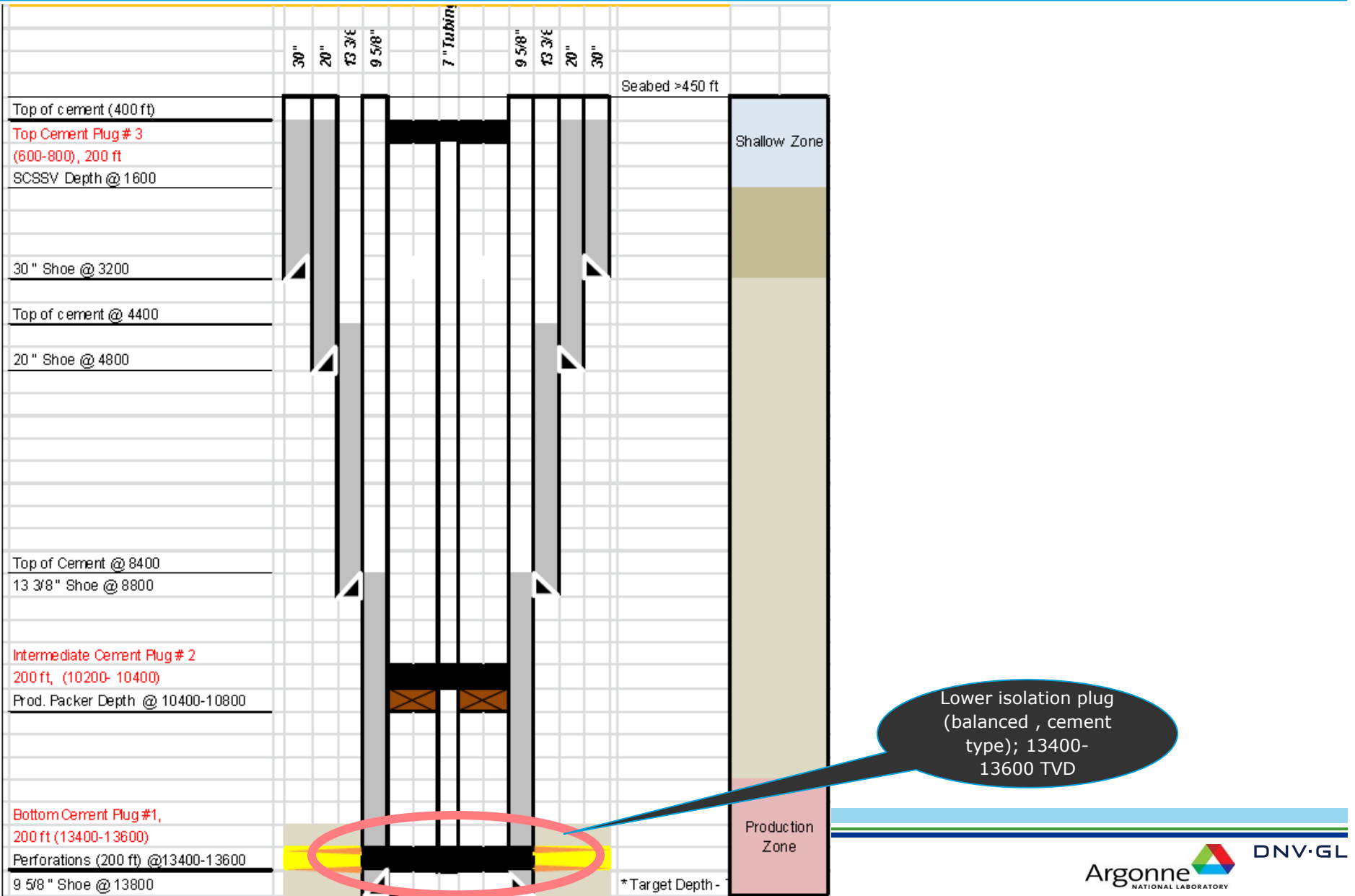
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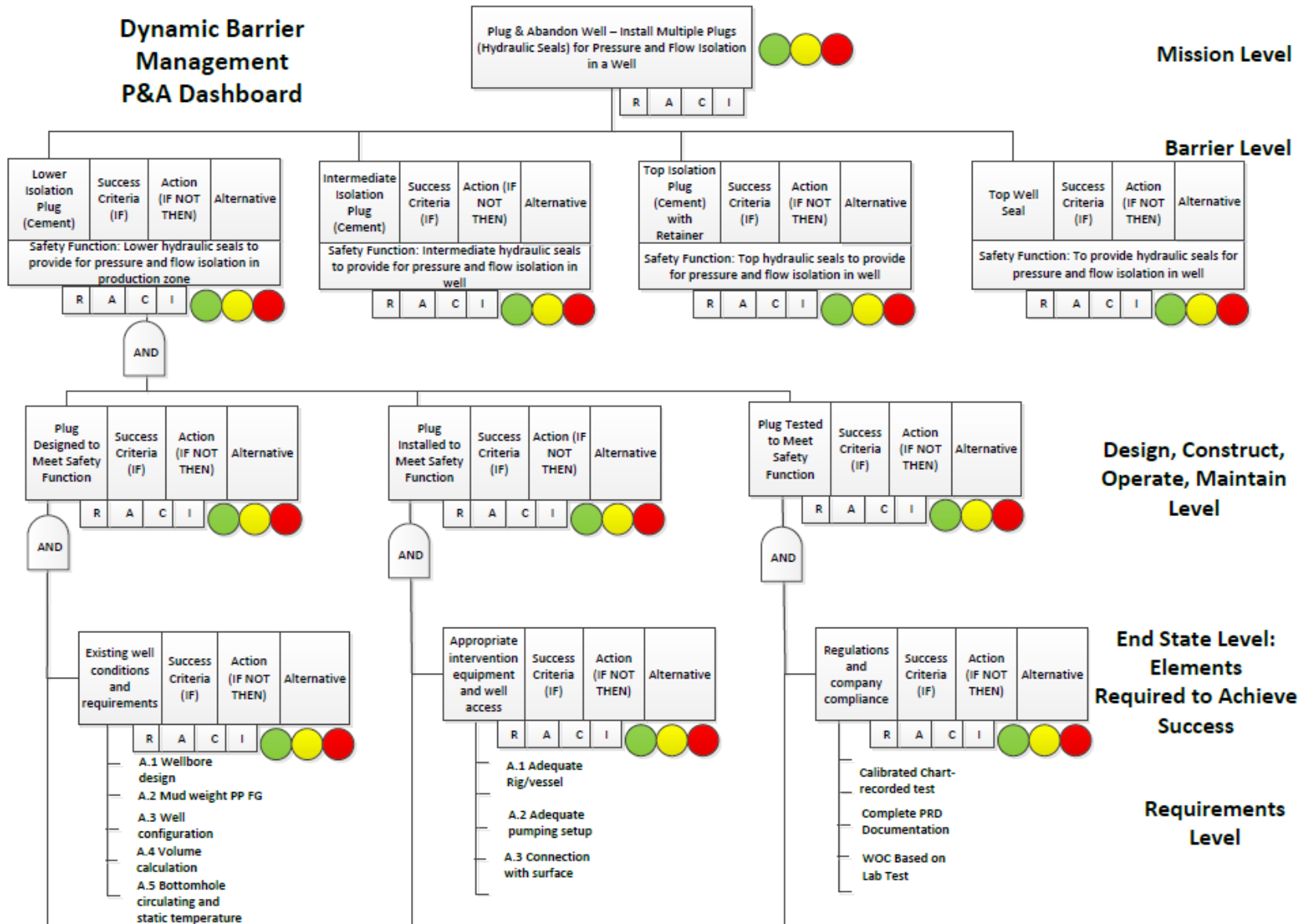
Region:

North America

JIP Plug & Abandon (P&A) Case Study: Develop Success Paths to Design, Install, and Test a Cement Plug



Dynamic Barrier Management Dashboard for P&A Case Study



Compliance Assessment Tree for P&A Based on 30 CFR 250.1715

Plug and Abandon Well – Install multiple plugs (hydraulic seals) for pressure and flow isolation in a well

AND

A. Submit BSEE-124

B. Isolation Plugs – Installation to meet safety function and compliance (30 CFR 250.1715)

OR

1. Provide isolation for zones in open hole

2. Provide isolation for zones in open hole below casing

3. Provide isolation for perforated zone currently open and not previously squeezed and isolated

4. Provide isolation for casing stub where the stub end is within the casing

5. Provide isolation for casing stub where the stub end is below the casing

6. Provide isolation annular space that communicates with hole and extends to mud line

Cement plug

Success Criteria:
A) Plug ≥ 100 ft. below the bottom to 100 ft above top of zones (oil, gas, fresh waters)

Cement plug

Bridge plug

Cement Plug* and Cement Retainer**

Success Criteria:
A) Placement via displacement
B) Plug ≥ 100 ft. above and below deepest casing shoe

Success Criteria:
A) Plug set 50-100 ft. above shoe with 50 ft cement on top of bridge plug

Success Criteria:
*A) ≥ 100 ft below casing shoe
*B) ≥ 50 ft. above retainer
**A) 50-100 ft. above casing shoe

AND

Method to squeeze cement to all perforations

Cement plug

If the perforated zones are isolated from the hole below, you may use any of the plugs

OR

Success Criteria:
A) Placement via displacement
B) Plug ≥ 100 ft. above and below perforated interval

OR

Cement plug

Cement plug

Cement Plug* and Cement Retainer**

Success Criteria:
A) ≥ 100 ft. above and below stub end

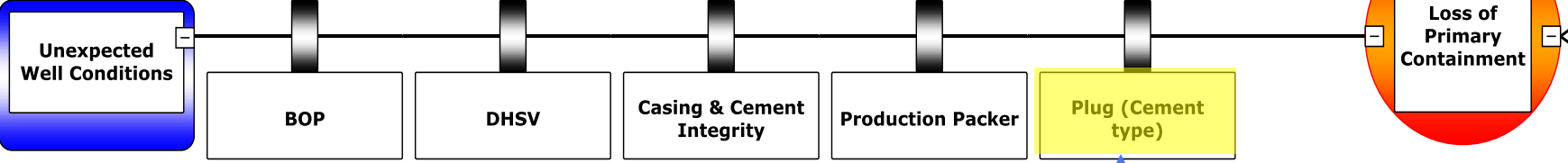
Success Criteria:
A) Length ≥ 200 ft.
B) Bottom of plug ≤ 100 ft. above stub end

Success Criteria:
*A) 50-100 ft. above casing shoe
**A) ≥ 100 ft below casing shoe
**B) ≥ 50 ft. above retainer

Cement plug

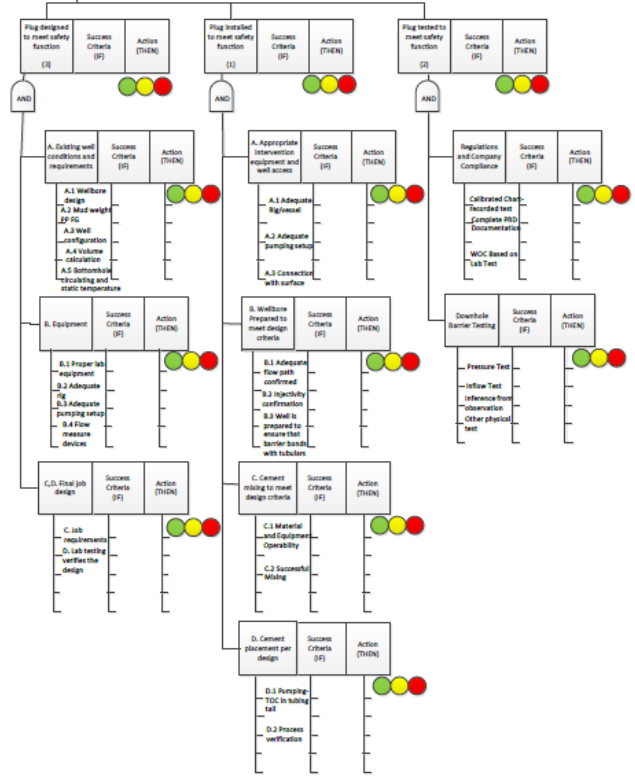
Success Criteria:

Application of Dynamic Barrier Management to the P&A Case Study



Bow Tie Diagram

Response Tree:
Success Path for
Cement Plug



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Summary

- The barrier-success path approach has been applied to industry projects:
 - Post-accident assessment of corrective actions for major pipeline leak events
 - Erosion integrity management for offshore production installation
 - Design and regulatory approval for a BOP control system
- JIP participants believe the approach can be applied within their organizations
- The success path dashboard provides:
 - A systematic way to continuously monitor and communicate status of well integrity across operators and contractor organizations
 - Guidance for action when unexpected conditions are encountered
 - A neutral framework to establish decision criteria and communicate compliance status between operators and regulatory authorities

Potential applications for underground gas storage

- Post-accident assessment of major events
- Identify common factors and lessons learned across events
- Systematically identify success paths and information requirements for monitoring well integrity barriers
- Establish decision criteria and guidance for action for unexpected conditions
- Continuous monitoring of well integrity within and across assets
- Systematic, neutral framework for assessment of regulatory requirements and industry-regulator communication

Questions?

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SAFER, SMARTER, GREENER

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