WELL CONSTRUCTION

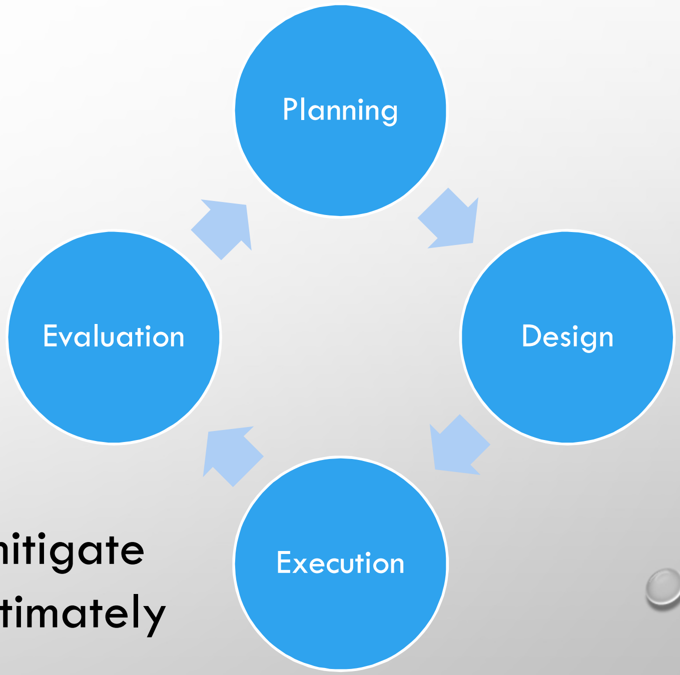
A RISK MANAGEMENT APPROACH

INTRODUCTION

- An integrated approach to well construction:
  - Sets clear objectives for all stakeholders
  - Identifies risk, uncertainties, and mitigations
  - Considers well integrity in design and construction for the intended lifecycle
  - Ensures increased efficiency and reduced time and cost
- This presentation will focus on the role Drilling plays in the well construction process and how decisions made in the early phase of the project impact long-term well integrity and ultimately the production capacity of the well.

WELL CONSTRUCTION PROCESS

- The well construction process should be
  - ➢ Tailored to meet the company's specific needs
  - ➢ Reflect the actual risks of the well
  - ➢ Flexible enough to address change
- Commitment to the process allows us to identify and mitigate risk, to design wells based on its expected life, and ultimately to increase efficiency and production of the well.



PLANNING

Planning

- The planning phase includes:
  - ➢Identification and contribution of key stakeholders
  - ➢Identification of subsurface data requirements
  - ➢Identification of risk
    - o Risk Matrix
    - o Risk Register
- It is through the planning phase that we determine the design requirements to ensure integrity through lifecycle well.

PLANNING

KEY STAKEHOLDERS

➢ Subsurface	Identifies hazards, formation profile, directional profile
➢ Drilling	Ensures target zone or zone of interest is drillable
➢ Completions	Ensures the zone can be completed
➢ Production	Identifies what is required to produce the well for the long term
➢ Abandonment	Identifies potential issues / abandonment requirements
➢ Supply Chain	Manages contracts, pricing agreements, materials, long lead items
➢ Safety / Regulatory	Identifies health, safety, environment, and regulatory requirements

PLANNING

SUBSURFACE INFORMATION

- Preliminary x and y coordinates / well trajectory
- Target zone / KOP / tolerances
- Offset well data – Drilling history / production history / environmental issues
- Shallow hazards – Gas / water
- Geology – Depths / permeability / salt / shale stringers / loss zones / formation stability
- Reservoir data – Fluid types / pressures / temperatures / expected H_2S or CO_2
- Current and projected reservoir conditions
- Injection pressure data
- Fracture pressure / pore pressure / over pressured / pressure transitions / depleted zones
- Data acquisition – Logging requirements

Accurate subsurface data is one of our biggest challenges as an industry

PLANNING

RISK IDENTIFICATION

- Risk is defined as
  1. *The possibility of harm damage, injury, liability, losing something of value, danger, a hazard.*
  2. *Negative occurrence caused by vulnerabilities; may be avoided through preemptive action.*
  3. *Risk perception is the subjective judgment people make about the severity and probability of a risk and may vary person to person.*
- Risk is a perception, and dynamic, depending on the team lead, stakeholders, company, etc.
- The tolerance for risk will vary depending on temperament, experience, objectives, and goals.
- The use of a risk matrix and a documented risk register helps to mitigate this uncertainty.

PLANNING

RISK MATRIX

- A tool to rank risk based on consequence or impact, and probability of the event happening.

Rank	1	2	3	4
Category	**Minor**	**Moderate**	**Major**	**Catastrophic**
Reputation	No media	Local media interest	Regional/ National media interest	National / International media interest
Health and safety	No injuries	First aid	Hospitalization	Fatality
Environment	Spill on lease	Spill off lease	Potential for public impact from release	Public health jeopardized
Time and cost	< 0.5 million	0.5 – 2 million	2 – 5 million	20 million

Example – Risk Matrix

Risk Matrix - Drilling and well process

Increasing impact	Health, Safety, Environment & Reputation - subcategories (ref. WR2266)					Increasing probability (pr project)				
	People's health and safety	Environment	Social impacts, human rights, integrity	Cultural Heritage	Reputation	< 1 % P1 Unlikely	1 - 5 % P2 Rare	5 - 25 % P3 Probable	25 - 50% P4 Likely	> 50% P5 Expected
I[illegible]	- Fatal[illegible] workforce - Serious injury/[illegible] 3rd party - Serious work related illness or exposure resulting in significant life shortening effect/death to workforce	- Adverse long term impacts on ecologically valuable natur[illegible] habitats (e.g. restitution time > 3 yrs) - Adverse impact on threatened species on a national level - Adverse impact on protected areas of national importance	- Adverse long-term impacts on multiple [illegible] time > 2 yrs) - Serious breach of labour rights (in particular freedom of association, child labour, forced/compulsory labour, and discrimination – e.g. against migrant labour)	Considerable damage - local or regional [illegible]portance - restoration required	- Negative wor[illegible]e news [illegible]age in media - Negative attention from important organisations					
I4	Serious injury, work related illness with absence from work, restricted work or permanent health effects	- Adverse medium term impacts on ecologically valuable natural habitats, or long term impacts on a significant part of such habitats (e.g. restitution time 1-3 yrs) - Adverse medium to long term impact on the population on one or more species - Adverse im[illegible]	- Adverse medium-term impacts on multiple households (restoration time < 2 years)	Notable damage - local or regional importance - restoration required.	-National negative exposure in mass media - Negative exposure from national authorities/regulators					
I3	[illegible]edical treatment injury [illegible]r work related illness [illegible]ith need for treatment	-Adverse short term impact on natural habitats (e.g. restitution time < 1 yrs) -Adverse short term impact on the population of one or more species - Adverse impact on protected areas of local importance	Adverse short-term impact on multiple households(rapidly restored)	Minor damage - local importance - no restoration required	Local/ regional negative exposure -in mass media, -from authorities and customers					
I2	First aid injury or work related illness/effect with minor impact on health and ability to function	-Very limited impacts on natural habitats - Very limited impact on population level or impact on key species on individual organism levels	Brief and non-measurable adverse impact on multiple households	Slight temporary disturbance	Negative exposure with limited importance					
[illegible]1										

PLANNING

RISK REGISTER

- Identifies risks and provides a baseline for original assumptions about the well.
- Assumptions made here form the basis of well design.
- The risk register is
  - Completed by key stakeholders prior to the start of operations
  - Based on the full well development process – design thru abandonment
  - Based on available data
  - Evaluated and updated throughout the process

Example – Risk Register

Risk Elements			Initial Risk				Risk Improvement Actions				Remaining Risk			
R. ID	Risk	Description	Prob	Impact: HSE	Impact: OBJ	Impact: TC	Action	Status	Responsible	Due Date	Prob	Impact: HSE	Impact: OBJ	Impact: TC
1	**Pre-Drilling**													
1.1	Supply of long lead items not adequate to keep up with demand	**Cause**: Poor forecasting, change in well design, changing subsurface conditions **Impact**: Delays to execution, higher costs	P1	I1	I1	I2	1. Proper forecasting and procurement of long lead items	Open	1. Procurement		P1	I1	I1	I2
1.2	Unable to keep up with drill pipe inspection requirements	**Cause**: Frequency and management of drill pipe inspection program is not adequate **Impact**: Increased instances of drill pipe failure	P1	I2	I3	I3	1. Ensure DP inspection requirements and schedule are included in Drilling Rig tender 2. Include qualified DP inspectors in Tier 3 contracts	Open	1. Drlg Supt 2. Drlg Engr / Drlg Supt		P1	I1	I2	I2
1.3	Inexperienced Contractor personnel	**Cause**: Poor contract specifications, availability of experienced personnel, high industry activity level **Impact**: Additional time/cost, potential HSE incidents	P4	I3	I2	I2	1. Tender specs to include limits on greenhats (inexperienced personnel) 2. Tender specs to include service company use of mentoring program 3. Ensure service company is following greenhat and mentoring program	Open	1. Drlg Engr 2. Drlg Engr 3. DSS / Drlg Supt		P3	I3	I2	I2
1.4	Unable to manage cuttings at surface	**Cause**: Bottlenecks in transportation of cuttings from rig to reserve pit, improper sizing of shakers/desanders/desilters **Impact**: Additional time and cost, reduced penetration rate	P2	I2	I1	I2	1. Properly size cuttings handling equipment for hole size and flow rates 2. Develop and implement cuttings management plan 3. Ensure contract is in place with multiple contractors for cuttings disposal	Open	1. Drlg Engr / Drlg Supt 2. Drlg Engr / Drlg Supt 3. Drlg Engr / Procurement		P1	I1	I1	I1
1.5	Incident occurs during simultaneous operations	**Cause**: Lack of coordination during simultaneous operations **Impact**: Damage to property, additional risk to personnel, lost production	P3	I4	I3	I3	1. Develop and implement SIMOPS plan for Eagle Ford	Open	1. Drlg Engr / Drlg Supt / O&M		P2	I3	I2	I2

HSE – Health, Safety, and Environment
OBJ – Well Objective
TC – Time and Cost

WELL DESIGN

Design

- Well integrity is

  "The application of technical, operational, and organizational solutions to reduce risk of uncontrolled release of formation fluids throughout the life cycle of the well". (NORSOK D-010)

- The fundamental well barrier system is determined by drilling in the design phase.

- The casing string, connections, cement integrity, and cement bond form the barrier system and are critical to the integrity of the permanent P&A barrier.

- The design phase of well construction mitigates our long-term liabilities.

WELL DESIGN

Long-term Well Integrity Risks	Cause
Flow to surface	Casing integrity - Corrosion, poor design, reservoir change
Flow to surface	Casing integrity - Wear, damage, poor handling, blowout
Ground water contamination	Cement integrity - inadequate cement, poor design Casing integrity - inadequate information, poor design
Surface casing vent flow	Cement integrity -poor cement setting
Annular Pressure	Cement integrity - connections leaking
Crossflow between zones	Cement integrity - no zonal isolation, cement tops / placement

Licensees must maintain casing integrity for the life of the well, including post-abandonment

WELL DESIGN – CASING FAILURE

CAUSE

➢ Steel degradation (corrosion)	Function of pH, temperature, salinity, partial pressure CO_2 /H_2S
➢ Environmental impacts	HPHT, thermal loads, tectonic areas, pressure cycles, salt stringers
➢ Loads	Burst, collapse, axial, drilling, cementing, production, service loads

IMPACT: Flow to surface, crossflow, blowout

MITIGATION:

- ➢ Consider corrosion-resistant alloys
- ➢ Consider future use – CO_2, water/waste injection
- ➢ Consider loads from start of operations through to the end of production
- ➢ Design to accommodate changes in the reservoir
- ➢ Increase design factors (burst / collapse / axial load)
- ➢ Upgrade the casing string / connections

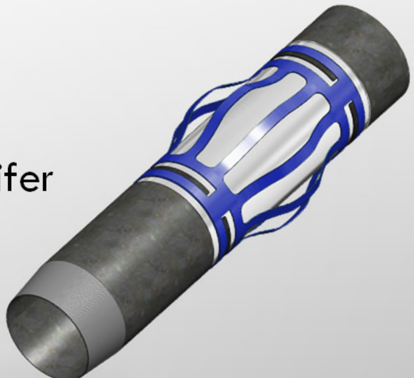
WELL DESIGN – CEMENT INTEGRITY

CAUSE

➢ Poor cement quality	Lack of subsurface information, poor design
➢ Poor cement placement	Lack of subsurface information, poor execution

IMPACT:

- ➢ Casing failure – external corrosion
- ➢ Contaminated non-saline groundwater zones / hydrological changes to the aquifer
- ➢ Failure to isolate potential hydrocarbon zones



MITIGATION:

- ➢ Evaluate cement quality – cement design, conventional cement vs. specialized,
- ➢ Implement procedures for placement – use centralizers, use of spacers, and a pre-flush
- ➢ Verify placement / TOC using logging while drilling (LWD)
- ➢ Conduct remedial cementing

EXECUTION

Execution

The drilling program is the means of connecting the design with the field operations.

The drilling program should

- Identify and define well target length, depth, and geo-steering window with tolerances
- Identify collision avoidance criteria
- Contain all required well specific information/calculations for performing the activity
- Establish a fluid management plan for the operational phase
- Establish procedures and expectations
- Identify barriers and testing requirements

EXECUTION

MECHANICAL / PHYSICAL BARRIERS

- Equipment - BOPs, wellhead, MPD, packers, plugs
- Fluid management

OPERATIONAL BARRIERS - PROCEDURES

- Programs, procedures, and processes
- Daily operations, expectations

ORGANIZATIONAL BARRIERS - PEOPLE

- Drilling operations are dynamic / monitoring
- Training requirements

People play a significant part in the drilling program and ultimately long-term well integrity.

EXECUTION – CASING FAILURE

CAUSE

➢ Handling of pipe/ casing / materials	➢ Coating and liner damage
➢ Wear and deformations	➢ Off center drilling / casing wear ➢ Casing overpull when setting slips
➢ Connections	➢ Torque, sealing surfaces
➢ Well Control	➢ Pressure cycles

IMPACT: Flow to surface / crossflow between zones / blowout

MITIGATION:

- ➢ Procedures and expectations
- ➢ Training and qualified people

EXECUTION – CEMENT INTEGRITY

CAUSE

Cement failure after casing is in place	Cement failure after the cement is set
➢ Mud filter cake	➢ Mechanical shock from pipe tripping
➢ Displacement techniques	➢ Casing expansion during pressure testing
➢ Wait on cement	➢ Compression of the cement during pressure testing

IMPACT:

- ➢ Flow to surface / crossflow between zones / blowout

MITIGATION:

- ➢ Clean the hole to remove the filter cake or mud, run pre-flush and spacers
- ➢ Centralize the casing, reciprocate and/or rotate during the cementing operation
- ➢ Training and qualified people

EVALUATION – POST PROJECT REVIEW

Evaluation

Project review should occur after each stage of the well construction process and at the end of the project

- Establish a project that allows you to improve on well time / cost reduction
- Revisit the risk register annually to ensure the risk profile has not changed
- Verify the assumptions are correct
- Ensure the well design is still valid based on new information.
- Evaluate execution and procedures critically
- Identify problems, identify solutions, make recommendations going forward
- Review of lessons learned

EVALUATION – QUALIFICATION OF BARRIERS

SHORT TERM BARRIERS

- Surface equipment – BOPs, wellhead, pressure testing
- FIT / LOT – stability of the formation, cement seal near the shoe
- Fluid – density, characteristics / contamination

LONG TERM BARRIERS

- Casing - Pressure testing, caliper logs
- Cement location - Real time data - pumping rate, volumes, densities
- Cement location / integrity - Cement evaluation logs

Determining the quality / location of cement is one of the biggest challenges during P&A.

EVALUATION - DOCUMENTATION

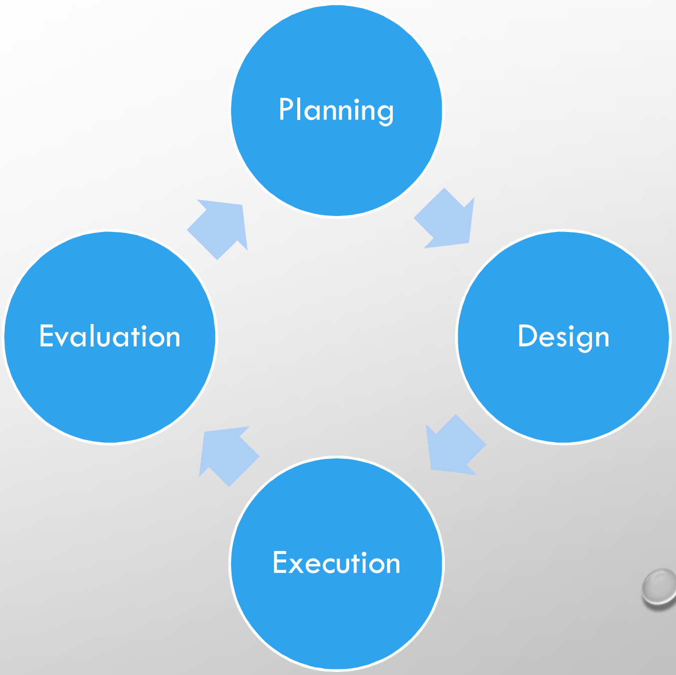
- **P&A INFORMATION CAPTURED DURING THE DRILLING PHASE**
  - Identification of competent formations during the well construction phase
  - Qualification of the formation as a possible well barrier (FIT, LOT)
  - Verification of cement integrity
  - Verification of a good cement bond
  - Verification of isolation between casing and the formation
  - Verification of top of cement
  - Record of events - casing wear / casing failures / well control

CONCLUSION

- A significant opportunity to improve performance and reduce the cost of the well is missed if we do not consider the full life cycle of the well during the drilling phase.

- Through a structured well construction process, we have the opportunity to get the right people at the table to plan, design, execute, and evaluate our progress.

- A team approach to well construction
  - ➢ Promotes sharing of knowledge / learning through the evaluation process
  - ➢ Balances the optimum well design to meet the drilling parameters or well control / containment vs. drilling with consideration for the life of the well.



Example – Risk Matrix

Appendix 4 – Assessment Matrix for Classifying Incidents
Alberta Energy Regulator

Table 1. Consequence of incident

Rank	Category	Example of consequence in category
1	Minor	• No worker injuries. • Nil or low media interest. • Liquid release contained on lease. • Gas release impact on lease only.
2	Moderate	• First aid treatment required for on-lease worker(s). • Local and possible regional media interest. • Liquid release not contained on lease. • Gas release impact has potential to extend beyond lease.
3	Major	• Worker(s) requires hospitalization. • Regional and national media interest. • Liquid release extends beyond lease—not contained. • Gas release impact extends beyond lease—public health/safety could be jeopardized.
4	Catastrophic	• Fatality. • National and international media interest. • Liquid release off lease not contained—potential for, or is, impacting water or sensitive terrain. • Gas release impact extends beyond lease—public health/safety jeopardized.

Table 2. Likelihood of incident escalating*

Rank	Descriptor	Description
1	Unlikely	The incident is contained or controlled and it is unlikely that the incident will escalate. There is no chance of additional hazards. Ongoing monitoring required.
2	Moderate	Control of the incident may have deteriorated but imminent control of the hazard by the licensee is probable. It is unlikely that the incident will further escalate.
3	Likely	Imminent and/or intermittent control of the incident is possible. The licensee has the capability of using internal and/or external resources to manage and bring the hazard under control in the near term.
4	Almost certain or currently occurring	The incident is uncontrolled and there is little chance that the licensee will be able to bring the hazard under control in the near term. The licensee will require assistance from outside parties to remedy the situation.

* What is the likelihood that the incident will escalate, resulting in an increased exposure to public health, safety, or the environment?

Sum the rank from both of these columns to obtain the risk level and the incident classification

Table 3. Incident classification

Risk level	Assessment results
Very low 2–3	Alert
Low 4–5	Level-1 emergency
Medium 6	Level-2 emergency
High 7–8	Level-3 emergency