Challenges in Managing Mercury in Field Development and Production

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Integrated Mercury Risk Management in Realizing 6 kboe/d from High Mercury Field Producer and Nearby Affected Fields and Terminals

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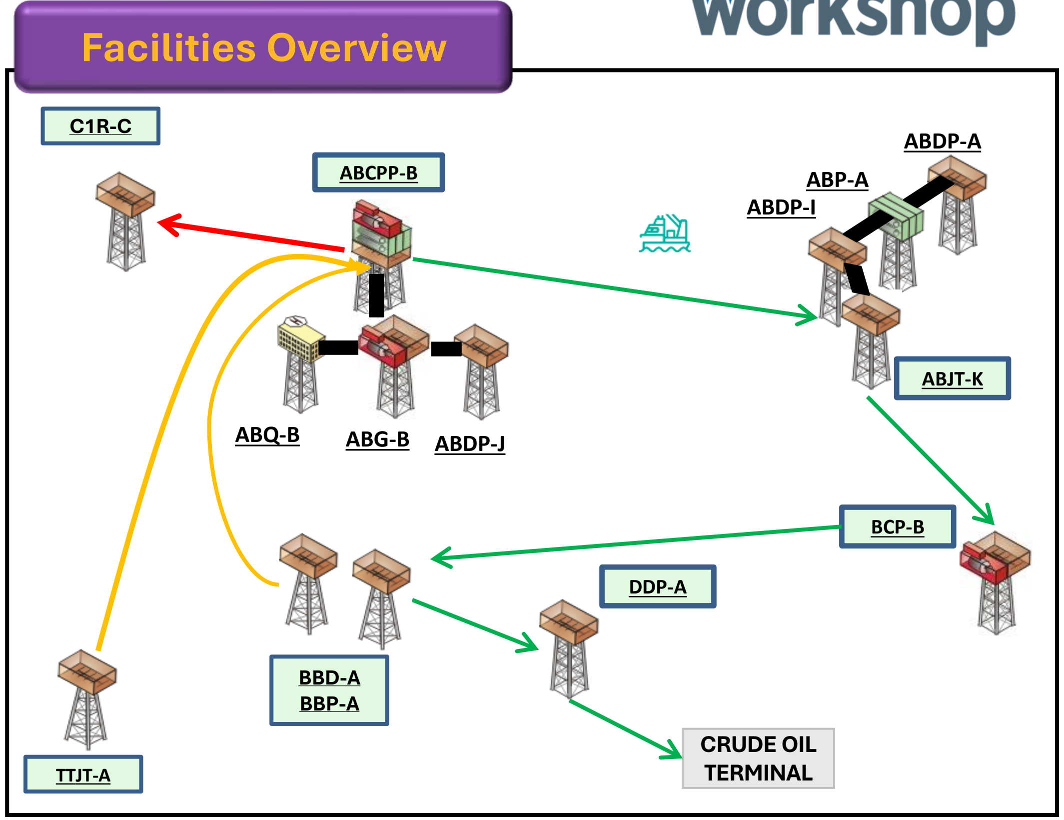
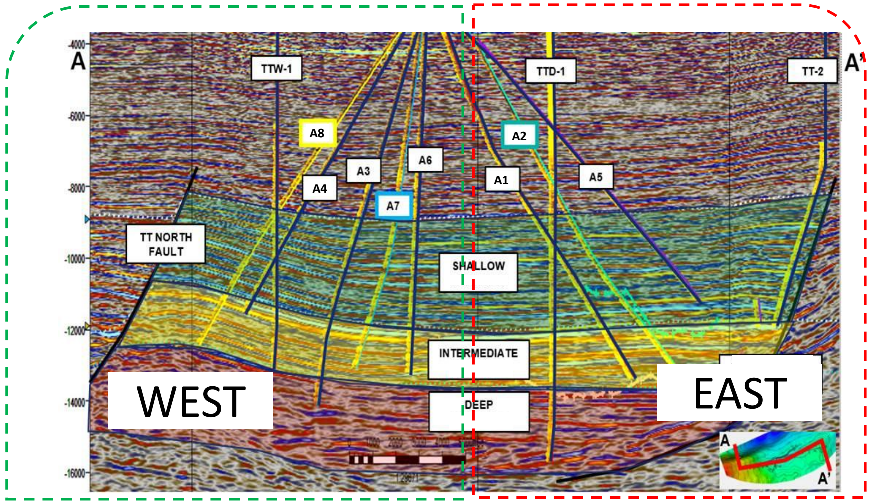
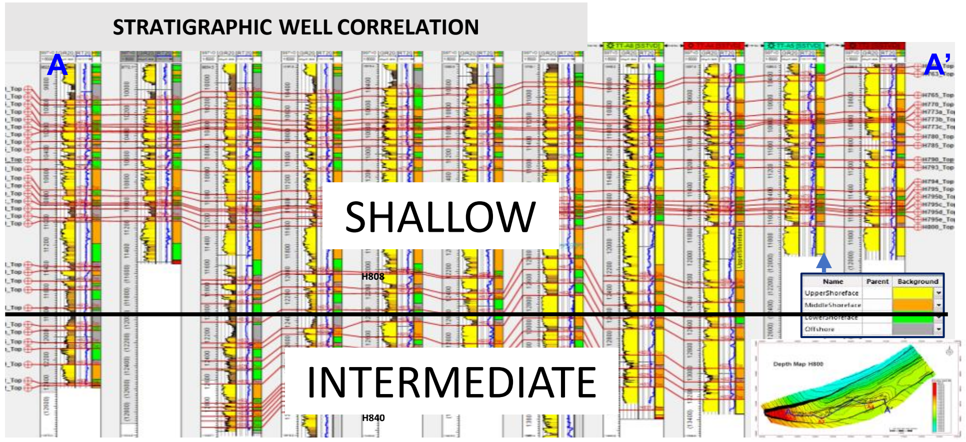
Field TT Summary

Location	25 KM to Shore in Sarawak Waters
Start production	July-2017
Well Type	Gas producers
Number of wells	8 Active wells
Reservoirs	• Middle Cycle V • Stacked sandstone / claystone layers • Natural depletion drive • TT Shallow, TT Intermediate, TT Deep
Production	250 MMscf/d, 6 kbcpd, 1kbwpd
Contaminant (normal days)	• Hg: ~300 ppb in condensate , ~50 ppb in water, ~0.8 µg/Nm3 in gas • H2S: ~ 16 ppm • CO2: ~2.5%







Executive Summary

Business case study

- TT Field has been estimated to produce lower gas after 8 years of plateau production
- Opportunity to blending high mercury producers before production decline

Proposal objective and value creation

- Proposal: To bean up and open up high mercury zone
- Target: 27 MMscf/d and 1.3 kbc/d

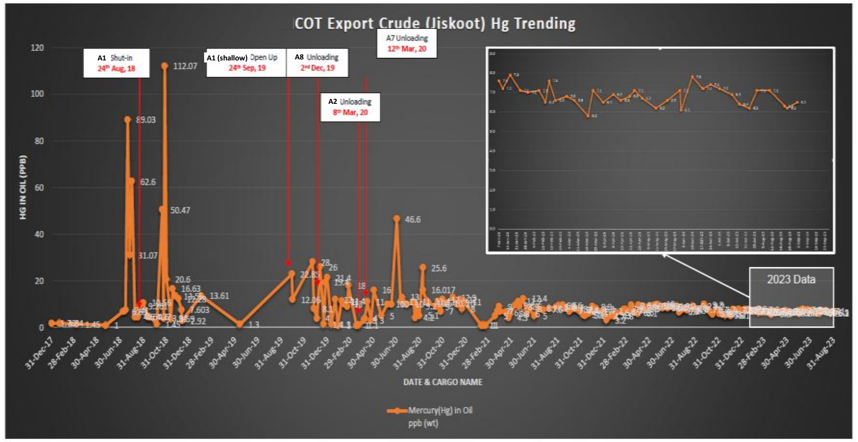
Key actions:

- Initializing operationalization strategy in managing and handling mercury pre and post TT job execution
- This project involves various discipline engineers within 6 fields and 1 terminal
- Focusing three (3) main areas; HSE, Asset Integrity and Production Quality

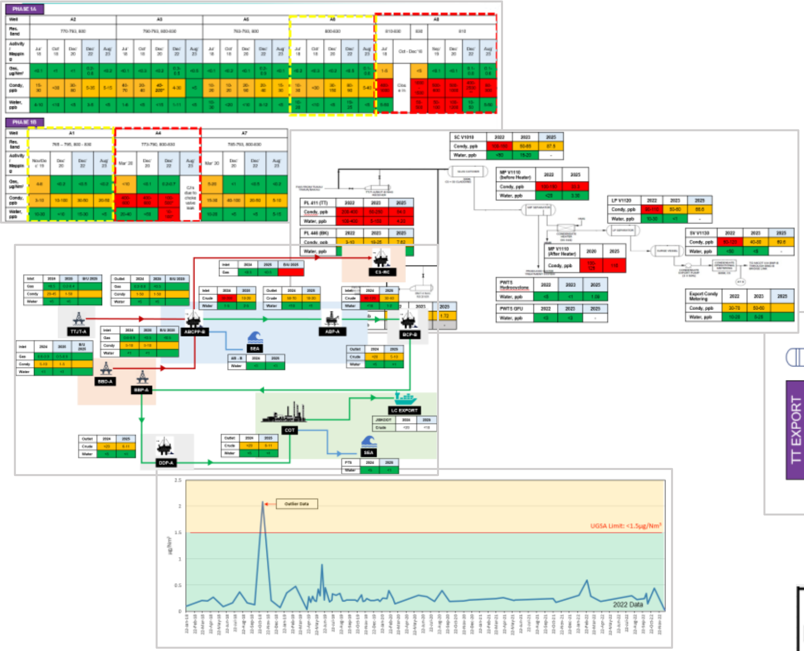
Cost estimation and Economic valuation

- HSE & minor asset integrity cost impact is estimated RM2.0MM (1st year), RM1.5 -1.6MM per year till end of PSC life
- Positive NPV@8%, High IRR and low UEC up to PSC life

Basis and Assumption



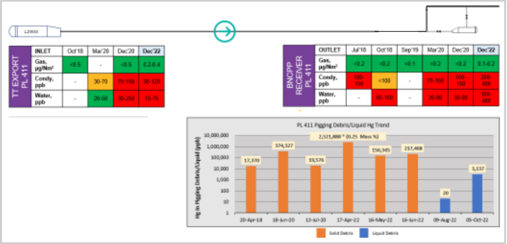
Notes:
- Hg concentration in Crude Export (Jiskoot Sample) for YR 2023 maintains below the 10ppb range



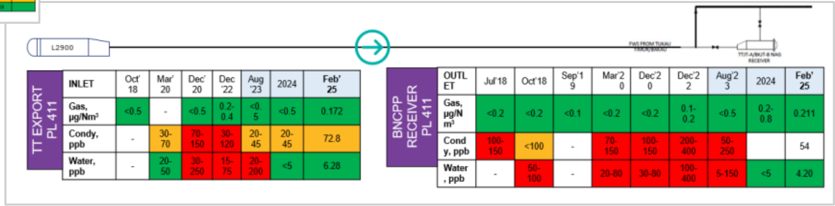
- TT Field started its production in 2017
- Two wells have been detected producing high mercury in cond n water
  - A1 ~2500 ppb, 1500 ppb
  - A2 ~600 ppb, 100ppb
- Mercury source is from TT Intermediate reservoir (2 zones)

- During well unloading, mercury reading was reported RED at export crude
- Immediate response to shut in the lowest bottom zone of well-A1 and production curtail at well-A2

- Establish database based on routine activities:
  - ✓ Sampling
  - ✓ Mercury mapping
  - ✓ Mercury speciation
  - ✓ Pigging debris analysis



- Historical mercury trending from TT Field (inlet & outlet of FWS pipeline):
  - ✓ Gas: < 0.5 μg/Nm3
  - ✓ Cond: 20 – 400 ppb
  - ✓ Water: <5 – 400 ppb



TT EXPORT PL 411 INLET	Oct' 18	Mar' 20	Dec' 20	Dec '22	Aug '23	2024	Feb' 25
Gas, μg/Nm³	<0.5	-	<0.5	0.2-0.4	<0.5	<0.5	0.172
Condy, ppb	-	30-70	70-150	30-120	20-45	20-45	72.8
Water, ppb	-	20-50	30-250	15-75	20-200	<5	6.28

BNCPP RECEIVER PL 411 OUTLET	Jul'18	Oct'18	Sep'19	Mar'20	Dec'20	Dec'22	Aug'23	2024	Feb' 25
Gas, μg/Nm³	<0.2	<0.2	<0.1	<0.2	<0.2	0.1-0.2	<0.5	0.2-0.8	0.211
Condy, ppb	100-150	<100	-	70-150	100-150	200-400	50-250		54
Water, ppb	-	50-100	-	20-80	30-80	100-400	5-150	<5	4.20

- Limitation of production quality spec:

Risk	Hg in Liquid (Oil/ condensate)	Hg in Gas	Hg in produced water
LOW	<5 ppb	<1.5 ug/Nm3	<50ppb
MEDIUM	5-100ppb	1.5-50ug/Nm3	
HIGH	>100ppb	>50ug/Nm3	>50ppb

Note 1): References:- PTS60150204 and Note on Hg,Dec2017,Production Chemistry.
2)The Mercury range for gas is modified as per the Tukau Timor UGSA Specification(I,e 1.5 vs 5 ug/Nm3)
3) The Mercury range for produced water has been estbalished in accordance with Standard B (EQ,Reg.1974)

- Well-A1: mainly has elemental type of Hg (~1300 ppb)
- Well-A2: increasing trend in ionic type of Hg (~17 to 190 ppb)
- Inlet pipeline: early trend has high in particulate type (~400 ppb), recent more dominant to ionic type

Milestone

- Reserves estimation
- Reservoir Management plan revision
- Mercury blending assessment

- Risk Assessment sessions
- Technical review endorsement

- Refine risk assessment

- Operation Readiness check with operations of all facilities

- Project Specific Predictive Study on Mercury Risk by Industrial Hygiene

Baseline Mercury Mapping

- Chemical Health Risk Assessment (CHRA) scoping revision for all asset

- Pre-Medical surveillance for offshore crew
- Baseline / Advanced mercury training
- Monthly updates on operation readiness

Bean up and Open up zone

Fluid sampling

Results monitoring

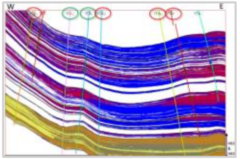
- Executing post job job Operationalization Strategy plan
- Postmortem (Retreat) on post job results for way forward
- Mercury mapping & speciation

Continuous surveillance routine (welltest, sampling, pigging, CI injection to pipeline)

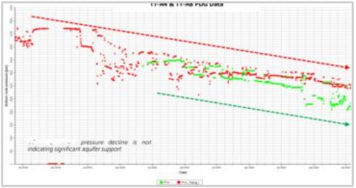
Important process flow

Reservoir Management Plan

- Then:
  - Western – Eastern production ratio (60:40) to minimize or control early water breakthrough at the Eastern flank due to the presence of aquifer



  - Minimize risk of Hg – Shut in lower zone of A1 and restraint output from A2
- Now:
  - Uplift ratio – based on pressure and water analysis sample (salinity <10)

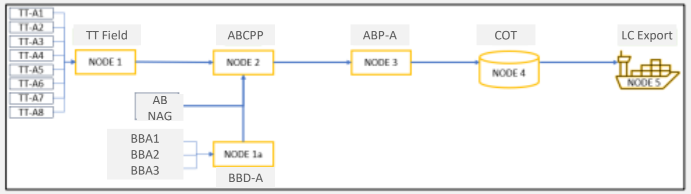


  - To unlock 54 Bscf of reserves

Mercury Blending

TECHNICAL BASIS/ METHODOLOGY

- Calculate Hg concentrations by using Hg mass (concentration, ppm) and volume fraction (%) based on liquid rates.
- Wells measured Hg concentrations in oil & water was given as input and calculated the Hg concentrations at respective nodes across network to COT.



- Match & tune measured and calculated data.

NODES	Measured		Calculated			
	Hg Mapping #5		Mass Fraction		Volume Fraction	
	OIL (ppb)	WATER (ppb)	OIL (ppb)	WATER (ppb)	OIL (ppb)	WATER (ppb)
Node1	120	200	74.4	4.4	68.7	14.6
Node 1a	20	1	29.7	0.4	4.4	3.4
Node 2	60	25	57.3	3.2	54.6	11
Node3	40	10	26.0	1.5	24.8	4.9
Node4	10	1	10.3	0.6	9.9	1.9
Node5	7	1	2.4	0.1	2.3	0.5

- *In general, Hg Mass and Volume fraction base calculations were found a good match with the measured Hg concentrations in Oil especially for Node 2, Node 4 & Node 5 which supports Hg concentration to be less than 10 ppb as currently monitored at Export MLC.*
- *Slight difference was observed at respective nodes, probably could be Hg behavior, drop out, uncertainty of measurements and volume*

- Perform few scenarios to assess Hg impacts.
- Identify the safe operating envelopes of Hg management.

High Case scenario from TTA1 & TTA2

	Input		Output			
			Mass Fraction		Volume Fraction	
	Oil (ppb)	Water (ppb)	Oil (ppb)	Water (ppb)	Oil (ppb)	Water (ppb)
TTA2	600	100				
TTA1	3000	1500				
Node 4 COT			45.0	9.8	41.8	17.0
Node 5 (EXPORT)			10.6	2.3	9.8	4.0

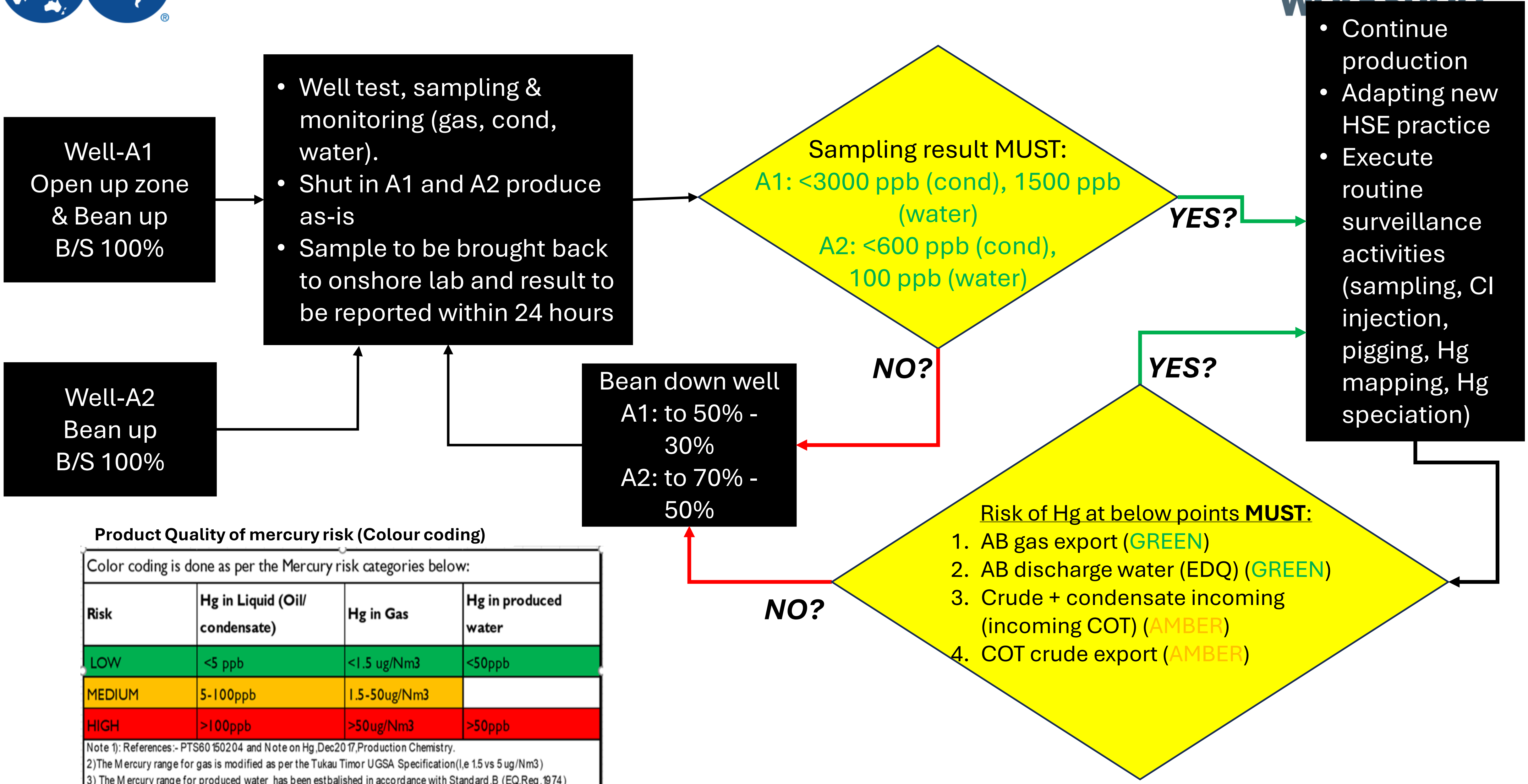
Risk Assessment

- HSE, Asset Integrity & Product Quality aspects
- Key risks:
  - Personnel exposure
  - Environmental impact
  - Corrosion led to leaking
  - Production quality did not meet acceptable limit and impact sales (UGSA) and to PETCO (crude) may lead to reputation damage
- Identify existing safeguard
- Setting up the mitigation plan, the action party and expected date
- Imposing pre and post Mitigation Strategy for Operationalization for TT field and affected assets
- Who? – SE, PC, OE, HSE, MCI, IPP

Surveillance & Operational

- Establish baseline:
  - Airborne exposure
  - Solid disposal analysis from monthly routine pigging
  - Mercury Mapping of identified locations
  - Medical surveillance check-up
- Cost and economic evaluation assessment
  - Integrated HSE management
  - Asset integrity strategy

Decision tree of project



Product Quality of mercury risk (Colour coding)

Color coding is done as per the Mercury risk categories below:

Risk	Hg in Liquid (Oil/ condensate)	Hg in Gas	Hg in produced water
LOW	<5 ppb	<1.5 ug/Nm3	<50ppb
MEDIUM	5-100ppb	1.5-50ug/Nm3	
HIGH	>100ppb	>50ug/Nm3	>50ppb

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Operationalization Strategy

SPE workshop

Health, Safety & Environment

- Items: mercury analyzer purchase and calibration, PPE, CHRA revision, medical surveillance, training (awareness and advance), decontamination station, HDPE drum, scheduled mercury waste inventory.
- Affected facilities TT, AB, BB, BC, DD, C1, COT and the personnels

Pre practice (current)	Post practice
• PPE (selection based on benzene reading) • Minimum awareness of Mercury capability • Medical surveillance for benzene • Existing CHRA (low risk of mercury) • Mercury analyzer – standby or not available • No decontamination station • Not mercury facilities – no signage of mercury	• Declaration of mercury facilities • Update operating procedures to include risk to mercury • PPE (selection of PPE based on mercury airborne reading) • MUST have Mercury Awareness & Handling training • Medical surveillance for mercury • Revised CHRA for affected facilities • Establish decontamination facilities (trained personnel & tools) • Communicate to all contractors on presence of mercury • Mercury signage at identified high risk area

Production Quality

- 14 critical points of fluid sampling will be closely monitored
- A mercury blending and prediction simulation result depicts the expected mercury content is around 9 to 40 ppb at COT.
- Possibility of higher mercury content in crude and gas sales to be communicated to buyers

Asset Integrity

- Wells and flowlines: Duplex material. Close monitor realtime parameters
- Pipeline: Carbon steel material. Monthly pigging routine. Changing new CI for more effective in mercury contamination environment
- Facilities: Considering to change CPP GTC current labyrinth material from Aluminum to polymer (PEEK). Estimation cost of RM 10.0 MM is budgeted should mercury content higher in gas. (the potential damage to compressor is consider low due to low mercury content in gas).

[Open]

Cost and Economics

1. TT covers all the HSE cost from affected facilities
2. HSE items consist of mercury analyzer, PPE, training, medical check-up and decontamination station

Economic evaluation (HSE and minor asset integrity)

3. The cost impact is estimated RM2.0MM (1st year), RM1.5 -1.6MM per year till end of PSC life

Cost estimation (RM ,000)	1st year	2nd year	3rd year	
Mercury Analyzer* and calibration	425	21.5	21.5	**Cost for following years will be similar to 2nd and 3rd year on alternate basis**
Training	124	*Once every 2 years*	124	
Medical Check Up	196	196	196	
PPE	637	637	637	
Decontamination Station	12	12	12	
Disposal Drum	13	13	13	
Compatible CI	469	469	469	
	2,000	**1,460**	**1,580**	

4. Positive economic analysis:

Economic Result

NPV0%	NPV8.0%	IRR	UEC	Econ Limit	Breakeven	Payout
MM RM	MM RM	%	RM/boe	Date	Date	Month
225.91	170.32	High	2.45	9/2034	3/2025	0

Economic evaluation (HSE and major Asset Integrity)

5. Positive results of economic analysis of changing GTC's labyrinth which the cost around RM 10.0 MM (5th year)

Economic Result

NPV0%	NPV8.0%	IRR	UEC	Econ Limit	Breakeven	Payout
MM RM	MM RM	%	RM/boe	Date	Date	Month
218.02	164.30	High	4.15	9/2034	3/2025	0

6. Labyrinth change will depend on the result of mercury content in gas

Conclusion

SPE workshop

Prelim Results

- No Open up zone, only bean up
- The sampling was taken within a week after job execution

Well-A1	Well-A2
Gas: +5 MMscf/d Cond: +200 bc/d	Gas: +20 MMscf/d Cond: +800 bc/d
• Gas: 8 – 7500 µg/Nm3 • Cond: 50 – 140 ppb • Water: 3 - 35 ppb	• Gas: 2 - 1800 µg/Nm3 • Cond: 40 - 97 ppb • Water: 1 – 11 ppb

- Post blending (prelim result) at RC and COT:
  - ✓ Gas: 122 µg/Nm3
  - ✓ Cond: 8 – 25 ppb
  - ✓ Water: < 1 ppb

Challenges & Recommendation

- HSE preparation – Embracing new HSE practice for operation crew (i.e. offshore) especially during activities that potentially expose to mercury
  - Refine RA into multiple session
  - Conduct Predictive study for mercury risk with HSE Industrial Hygiene
  - Conduct monthly progress of pre-mitigation plan – ample time for back-up plan
- Unmanned platform – less visit, less surveillance (sampling)
  - Optimize visit to firm up surveillance schedule
  - Increase frequency of mercury mapping and surveillance at downstream location
- Unable to perform in-situ mercury analysis due to no proper storage for chemical analyzer
  - Daily trip prioritization for sampling
  - Prioritization of lab analysis within 24 hours
- High cost in managing mercury
  - Blending first
  - Strict surveillance routine – mapping
  - HSE management
  - Asset integrity strategy
- Well condition – HUD retrieval affect prolong schedule, incur higher cost of logistic
  - Lower down the UPC by having add perf at Well-A1 especially at shallow zone to blend with the lowest zone production