cmr Instrumentation

Uncertainty calculations

Ownership allocation by means of multiphase metering

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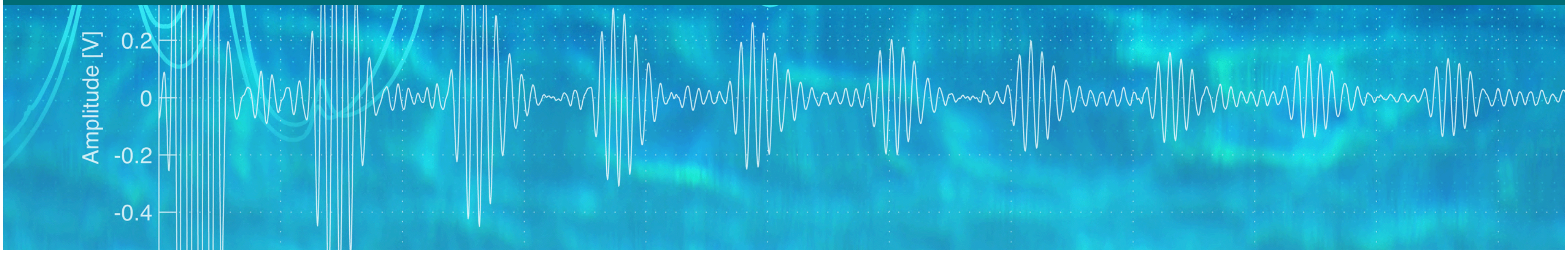


Presentation outline

- Measurement uncertainties and marginal field developments
- Multiphase flow meter measurement uncertainties
- Correlation
- Example 1 - Commingled flows
- Example 2 - By deduction
- Summary

Measurement uncertainties

High quality measurements are needed for:

- Fiscal allocation of the production from each license area
  - Normally necessary to measure the production from each license area separately for before it enters a common processing facility or flow line
- Production allocation metering and well management*
  - Calibration of reservoir models
  - Material balance
  - Mapping remaning reserves
  - Production optimisation

** Gjesdal A, Åbro E, Midttveit Ø (2008): Production Allocation of Tomorrow's Subsea Fields - Multiphase Meters, Test Separator or both?, SPE Bergen One Day Seminar 23 April 2008*

Marginal field developments

- Full fiscal metering may not be possible in marginal field developments because of the excessive cost compared to recoverable reserves
- New measurement concepts are being proposed based on use of multiphase flow meters or wet gas flow meters
- Considerations need to be made with respect to the technical robustness of the total metering concept
  - Redundancy, verification during operation, calibration, turn-down ratio, etc
- In particular measurement uncertainties need careful investigation at both meter and more superior / concept levels

Multiphase flow meter uncertainties

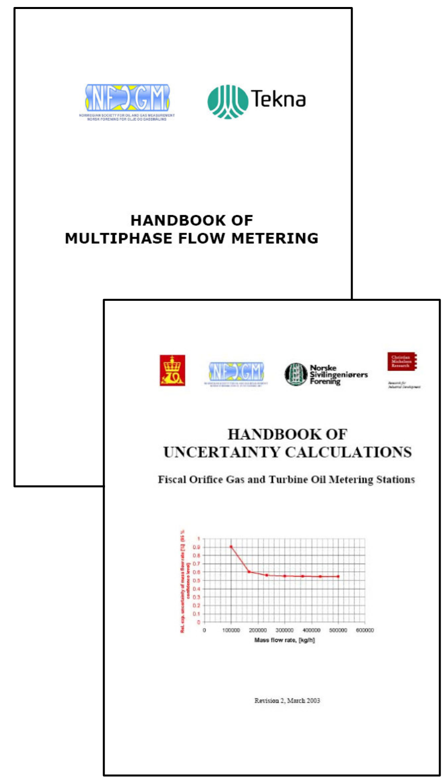
Input *
- PVT data
- Salinity

MPFM

Primary output
- Liquid rate
- Gas rate
- Water-in-liquid ratio

Secondary output
- Oil rate
- Water rate

- MPFMs must be evaluated with respect to combined expanded measurement uncertainty of the various measurements they perform
- Such an evaluation must include
  - uncertainties of the input quantities
  - functional relationships
  - implementation of models
- A full and complete *quantitative* uncertainty evaluation may not be possible...
- ...and is most certainly not sufficient



** Figure adopted from Gjesdal A, Åbro E, Midttveit Ø (2008): Production Allocation of Tomorrow's Subsea Fields - Multiphase Meters, Test Separator or both?, SPE Bergen One Day Seminar 23 April 2008*

Influence quantities and sensitivity coefficients

- A qualitative evaluation (quantitative if possible) should include consideration of influence quantities
- Influence quantities are quantities that are not the measurand, but still affect the result of measurement.
- Examples are (from the MPFM Handbook):
  - Flow regimes
  - Salinity variations
  - Additives
  - MEG / DEG / TEG
  - Methanol
  - Scaling, wax and hydrate
  - Pressure loss
  - Vibrations
  - Viscosity variations
  - Fluid properties
  - If intrusive parts: cavitation
  - Ambient conditions
  - Sand
  - Installation effects
  - EMC noise

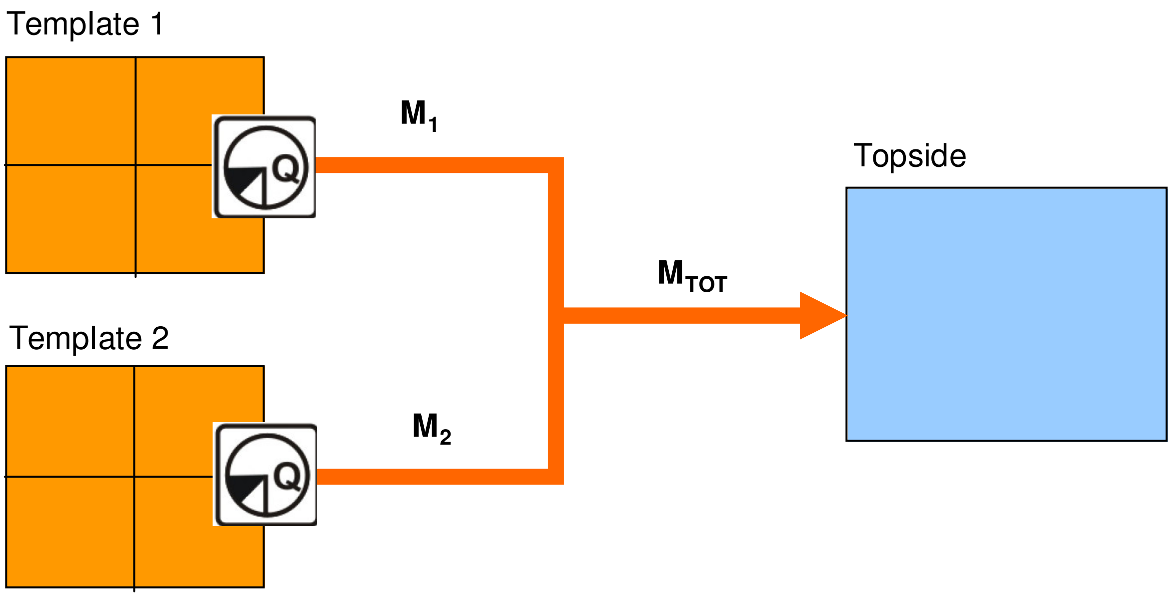
Correlation between measurements

- Common input quantities cause correlation
  - This is also true for influence quantities !
- Example 1:
  - Fiscal turbine oil metering station
    - Large covariance term due to Temperature, Pressure, volume correction factors, density and pulse counts are used both for proving and metering conditions
    - Reducing influence on the uncertainty
- Example 2:
  - Parallel metering runs
    - Common instrumentation, like density meters?
    - Common Prover?

Correlation between measurements

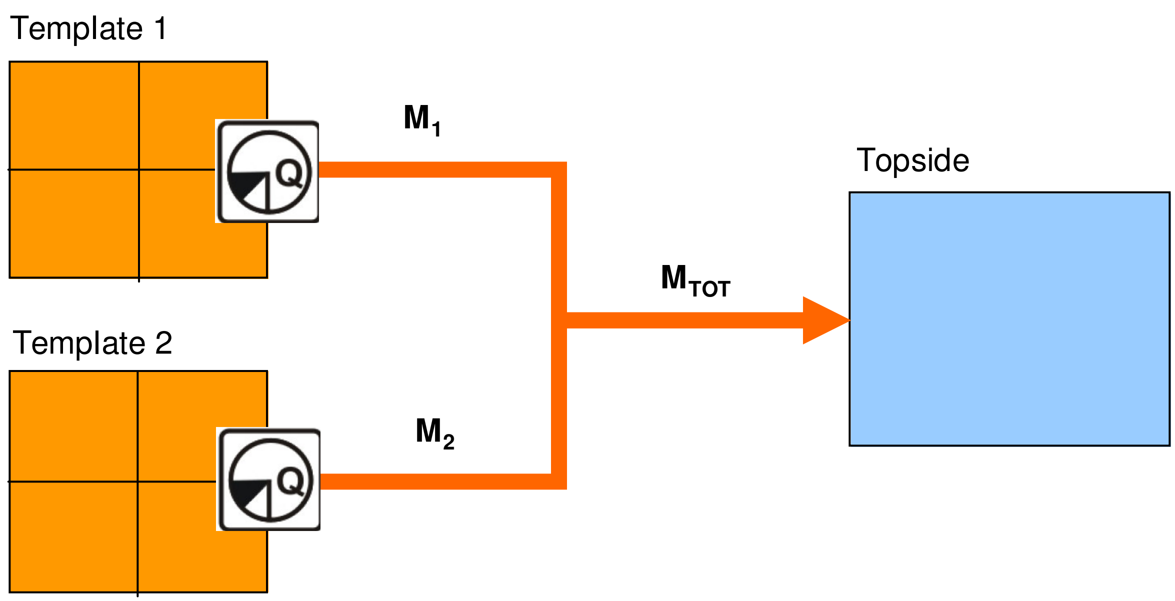
- Two equivalent methods exist to account for partial correlation
  - Covariance method
    - Described in the *GUM* and the *NFOGM Handbook of Uncertainty Calculations - Fiscal orifice gas and turbine oil metering stations*
  - Decomposition method
    - Described in the *NFOGM Handbook of Uncertainty Calculations - Ultrasonic fiscal gas metering stations*
    - The measurement uncertainty consists of an uncorrelated and a correlated part

Example 1 - Commingled flows



- Correlations between M_1 and M_2 could be due to (case dependent!)
  - PVT data (composition / fluid properties)?
  - Salinity?
  - Same manufacturer / technology?
  - Flow regime?
  - Scaling?
  - Chemical injection?

Example 1 - Commingled flows



$$M = M_1 + M_2$$

$$u(M)^2 = u(M_{1,u})^2 + u(M_{2,u})^2 + \left(u(M_{1,c}) + u(M_{2,c})\right)^2$$

$$\left(\frac{u(M)}{M}\right)^2 = \left(\frac{M_1}{M}\right)^2 \left(\frac{u(M_{1,u})}{M_1}\right)^2 + \left(\frac{M_2}{M}\right)^2 \left(\frac{u(M_{2,u})}{M_2}\right)^2 + \left\{\frac{M_1}{M}\frac{u(M_{1,c})}{M_1} + \frac{M_2}{M}\frac{u(M_{2,c})}{M_2}\right\}^2$$

Example 1 - Commingled flows

	M_1	M_2
Part of well flow	100%	0%
Uncorrelated uncertainty	4%	4%
Correlated uncertainty	3%	3%
Total uncertainty per well flow	**5%**	**5%**
Uncertainty of sum of the well flows	**5,0%**	

Note: All uncertainties are relative expanded uncertainties with 95% confidence level

Example 1 - Commingled flows

	M_1	M_2
Part of well flow	70%	30%
Uncorrelated uncertainty	4%	4%
Correlated uncertainty	3%	3%
Total uncertainty per well flow	**5%**	**5%**
Uncertainty of sum of the well flows	**4,3%**	

Note: All uncertainties are relative expanded uncertainties with 95% confidence level

Example 1 - Commingled flows

	M_1	M_2
Part of well flow	70%	30%
Uncorrelated uncertainty	5%	5%
Correlated uncertainty	0%	0%
Total uncertainty per well flow	**5%**	**5%**
Uncertainty of sum of the well flows	**3,8%**	

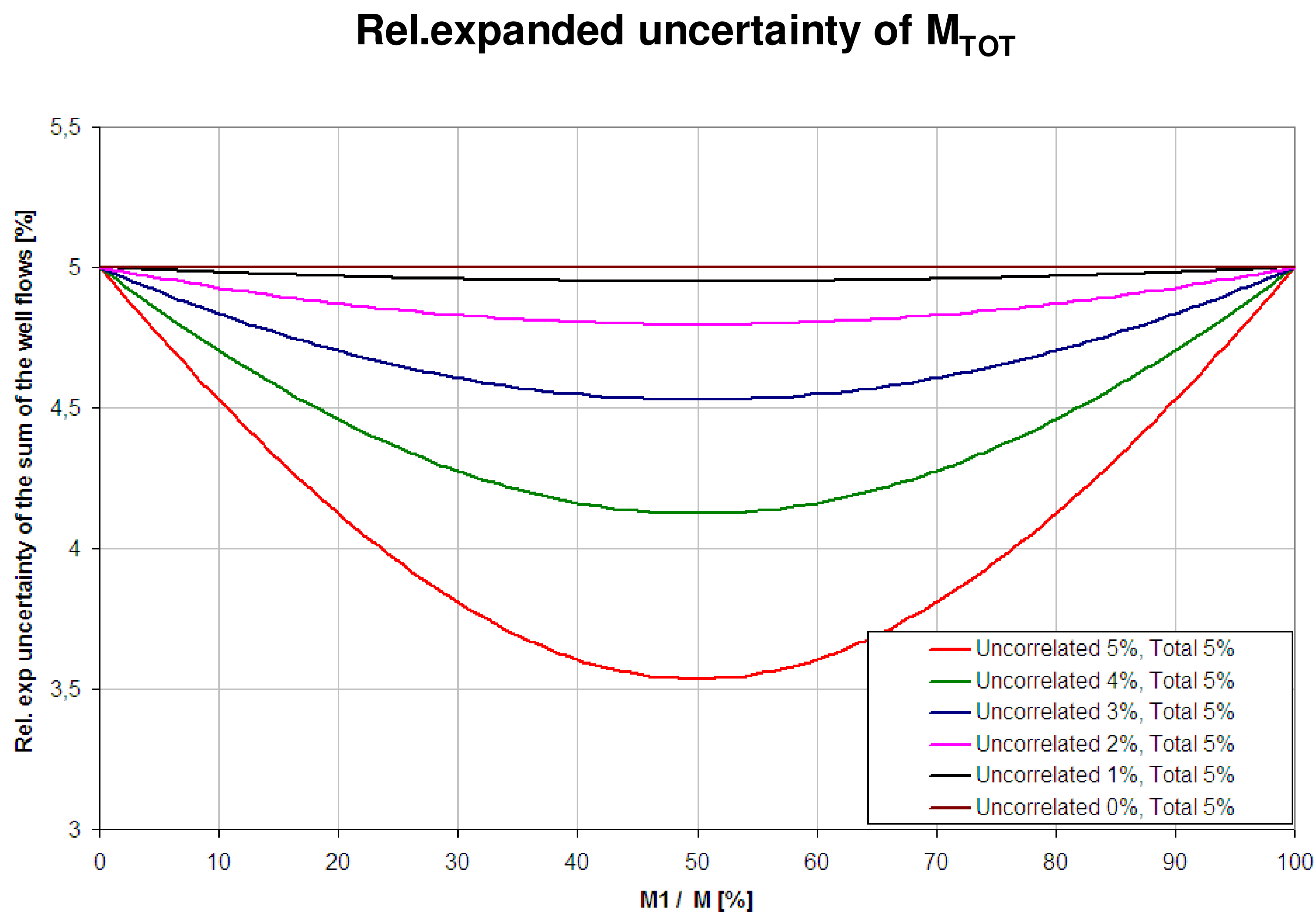
Note: All uncertainties are relative expanded uncertainties with 95% confidence level

Example 1 - Commingled flows

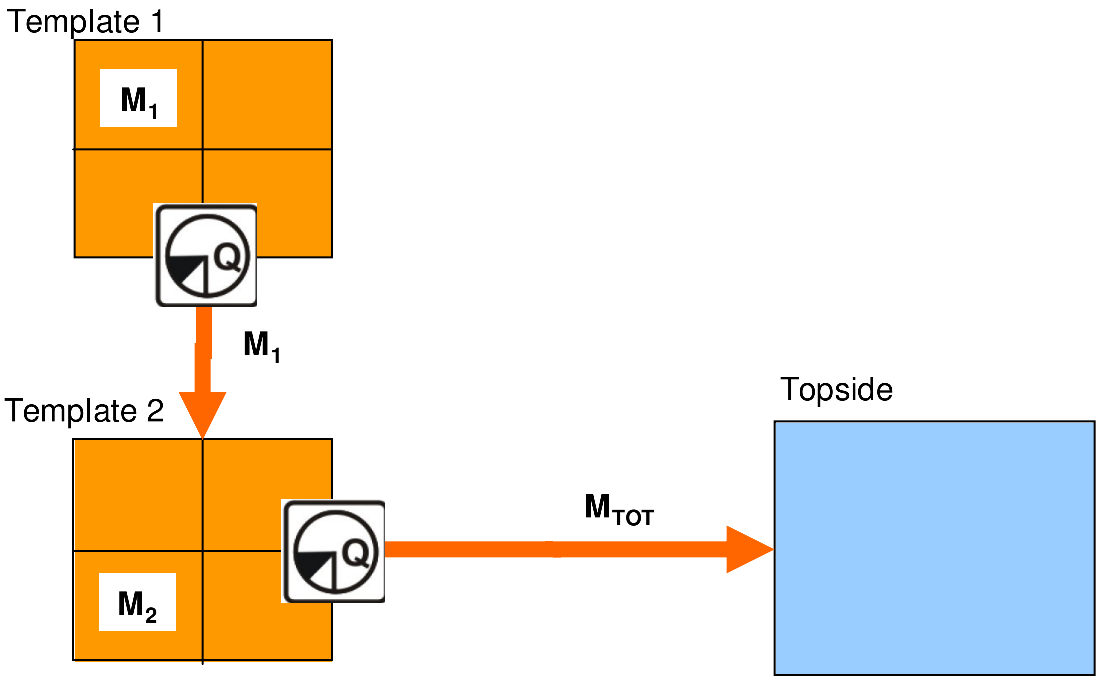
	M_1	M_2
Part of well flow	70%	30%
Uncorrelated uncertainty	0%	0%
Correlated uncertainty	5%	5%
Total uncertainty per well flow	**5%**	**5%**
Uncertainty of sum of the well flows	**5,0%**	

Note: All uncertainties are relative expanded uncertainties with 95% confidence level

Example 1 - Commingled flows



Example 2 - By deduction



$$M_2 = M - M_1$$

$$u(M_2)^2 = u(M_u)^2 + u(M_{1,u})^2 + \left(u(M_c) - u(M_{1,c})\right)^2$$

$$\left(\frac{u(M_2)}{M_2}\right)^2 = \left(\frac{M}{M_2}\right)^2 \left(\frac{u(M_u)}{M}\right)^2 + \left(\frac{M_1}{M_2}\right)^2 \left(\frac{u(M_{1,u})}{M_1}\right)^2 + \left\{\frac{M}{M_2}\frac{u(M_c)}{M} - \frac{M_1}{M_2}\frac{u(M_{1,c})}{M_1}\right\}^2$$

Example 2 - By deduction

	M_1	M_2
Production	0%	100%

Flows	M_1	M
Uncorrelated uncertainty	4%	4%
Correlated uncertainty	3%	3%
Total uncertainty per well flow	**5%**	**5%**
Uncertainty of the M_2 well flow	**5,0%**	

Note: All uncertainties are relative expanded uncertainties with 95% confidence level

Example 2 - By deduction

	M_1	M_2
Production	30%	70%

Flows	M_1	M
Uncorrelated uncertainty	4%	4%
Correlated uncertainty	3%	3%
Total uncertainty per well flow	**5%**	**5%**
Uncertainty of the M_2 well flow	**6,7%**	

Note: All uncertainties are relative expanded uncertainties with 95% confidence level

Example 2 - By deduction

	M_1	M_2
Production	50%	50%

Flows	M_1	M
Uncorrelated uncertainty	4%	4%
Correlated uncertainty	3%	3%
Total uncertainty per well flow	**5%**	**5%**
Uncertainty of the M_2 well flow	**9,4%**	

Note: All uncertainties are relative expanded uncertainties with 95% confidence level

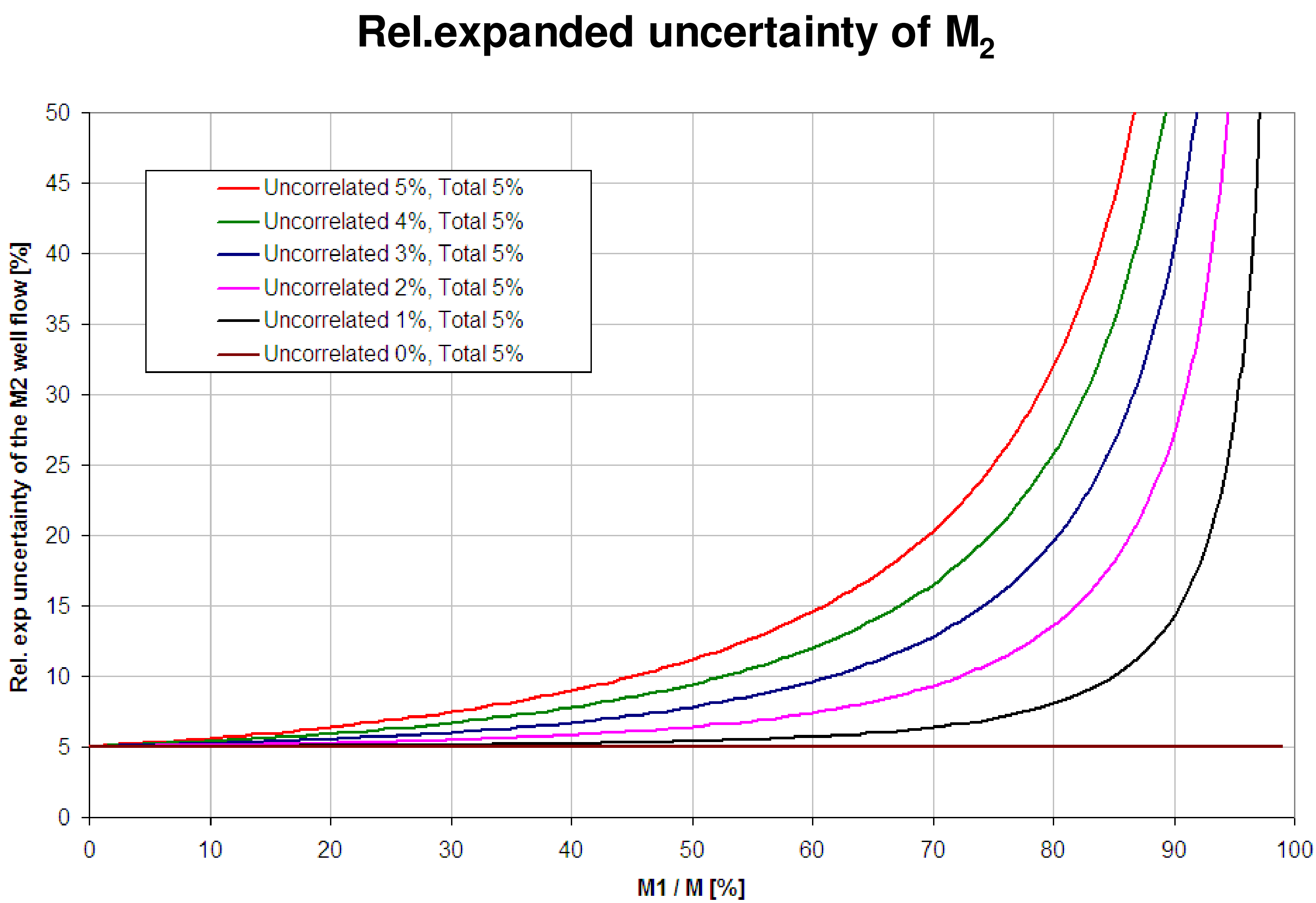
Example 2 - By deduction

	M_1	M_2
Production	70%	30%

Flows	M_1	M
Uncorrelated uncertainty	4%	4%
Correlated uncertainty	3%	3%
Total uncertainty per well flow	**5%**	**5%**
Uncertainty of the M_2 well flow	**16,5%**	

Note: All uncertainties are relative expanded uncertainties with 95% confidence level

Example 2 - By deduction



Summary

- The design and concept selection for marginal field developments may strongly influence the measurement uncertainty of both the existing and new production
- Thorough assessments of the resulting measurement uncertainty is required in each specific case
- Tie-ins to existing fields may in some cases deteriorate the production allocation from the existing fields
- Aim for measurement strategies for new marginal field developments that benefit from the reducing effects of statistics and correlations on measurement uncertainties