

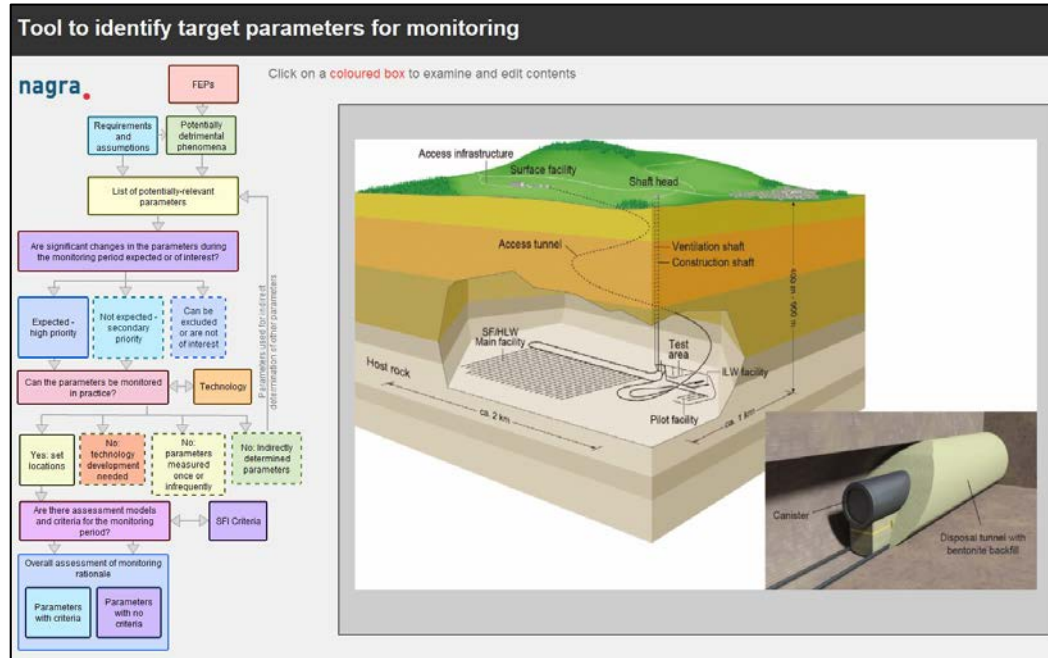
Derivation of Monitoring Parameters based on the Long-term Safety Assessment

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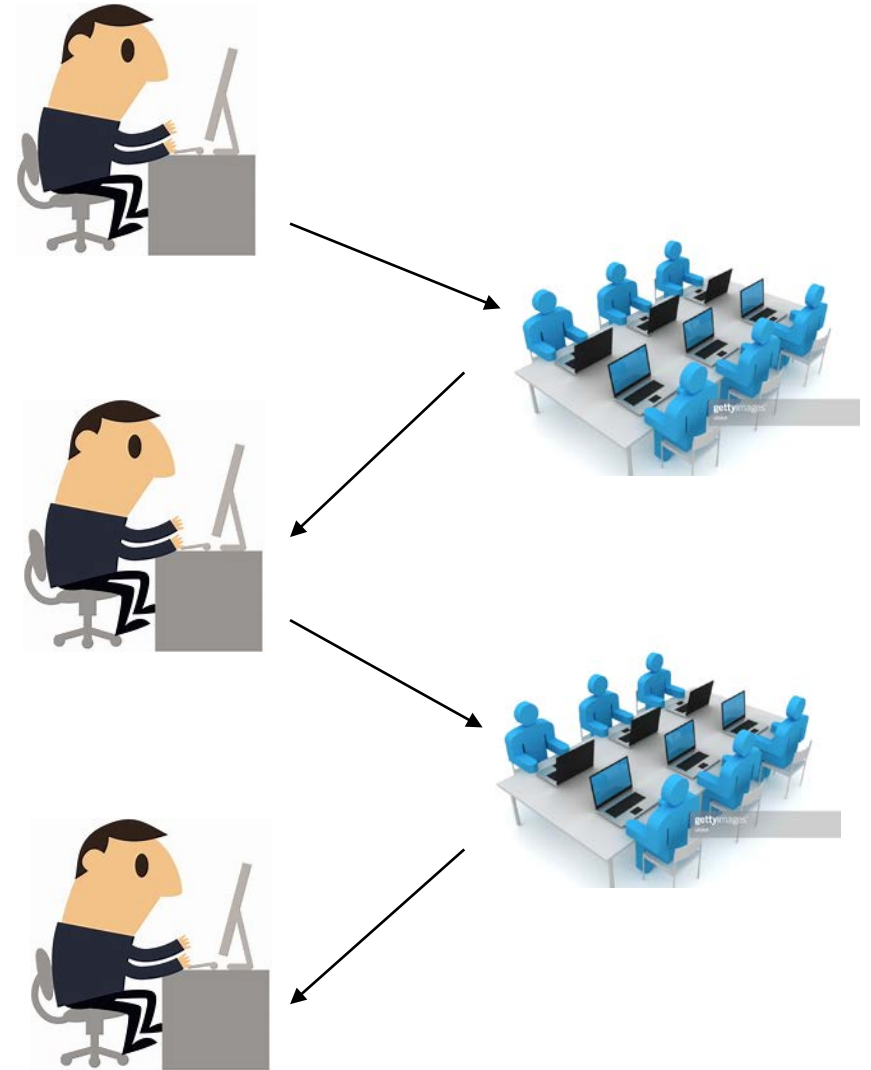
nagra.

Development of the methodology

- Methodology implemented in relational database tool (FileMaker)



- Refined iteratively in a series of meetings with chosen experts (co-authors)
- Methodology cross-checked against Modern2020 screening methodology

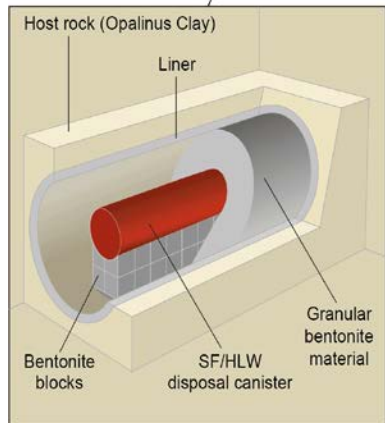
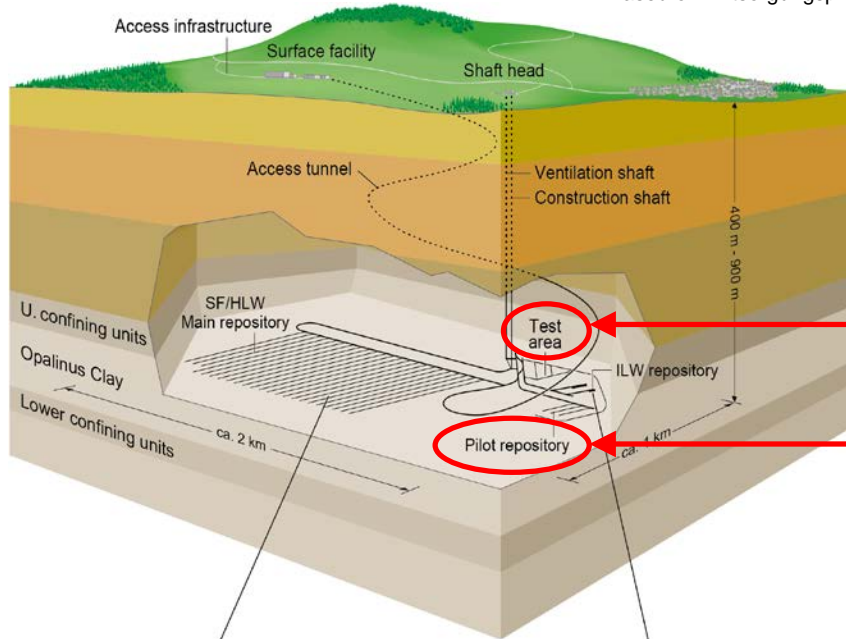


Methodology to identify monitoring parameters

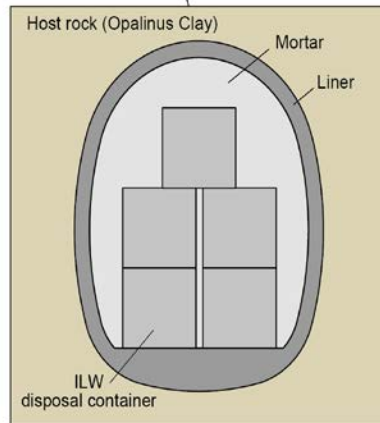
0. Describe **the system**
1. Identify key, **safety-relevant parameters**
2. Consider (without consideration of technical feasibility) whether monitoring of these parameters would be of **interest**, and set **priorities**
3. Consider **technical practicability** of monitoring those parameters identified as being of first and secondary priority
4. Identify whether **models** exist for evolution of those parameters that can be monitored and whether **safety-relevant criteria** exist that parameters should meet
5. Assess **overall rationale** for monitoring those parameters identified in Steps 2 through 5

START: System description

Based on Entsorgungsprogram 2016



Emplacement drift for SF/HLW



Emplacement cavern for ILW

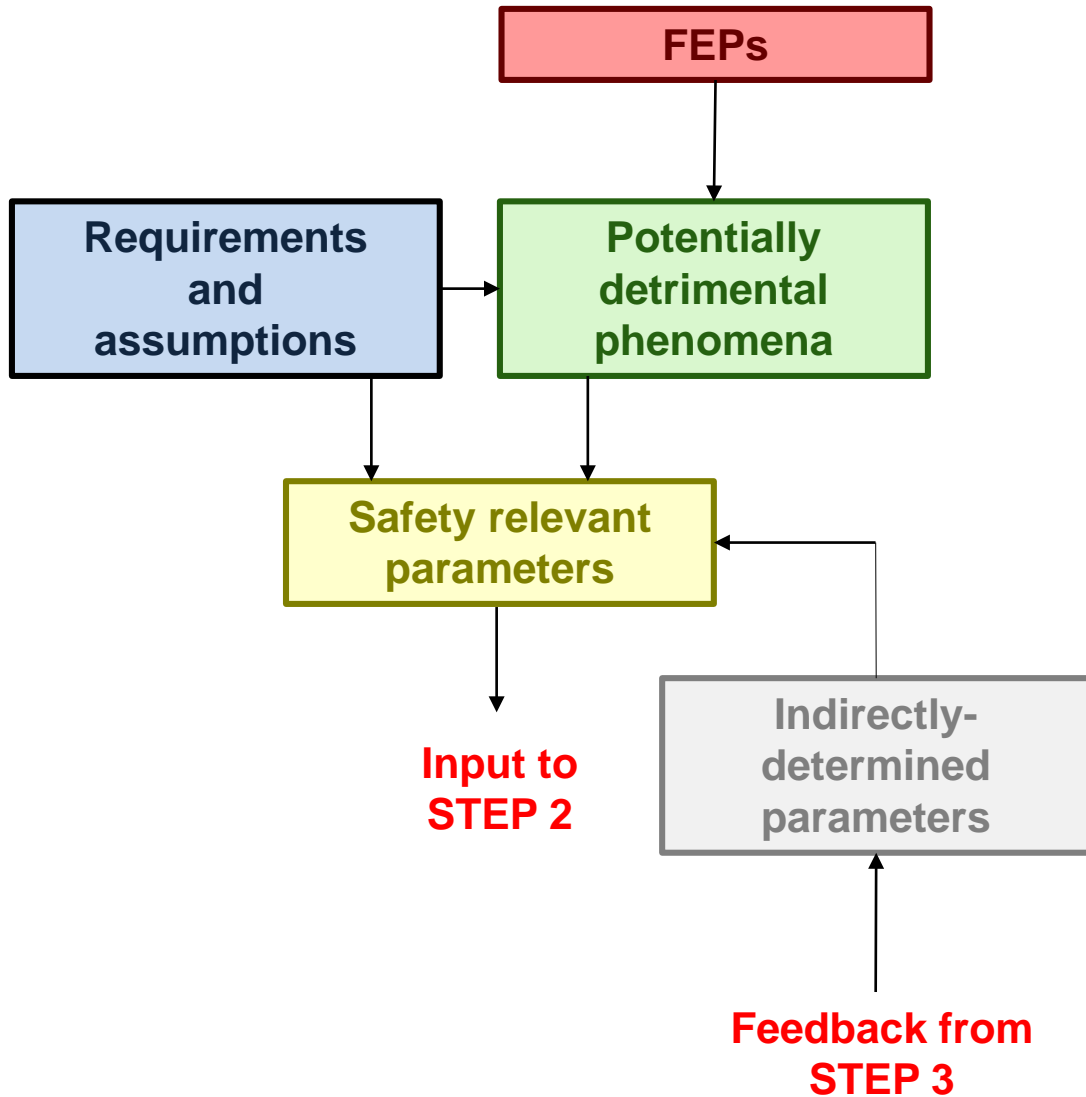
Test facility (site-specific URL)

- Not necessarily a single facility (rather, a series of experiments at different locations)
- Provide the **information required before the main facility can start operation** (and for subsequent decisions)

Pilot facility

- Contains **representative fraction of waste**
- Serves as **demonstration facility** for emplacement technology
- Provides information to better understand the **behaviour of barrier system** and to check **predictive models**
- Allows early detection of any **unexpected and undesirable system evolution**
- Provides **input for decisions** regarding commencement of operations and eventually the closure of entire facility

STEP 1: key, safety-relevant parameters



Category*	Definition
Requirements and assumptions	Define safety-related requirements on the overall system and on sub-system components (in particular, the canister, buffer and host rock) and/or reference assumptions for safety assessment
Potentially detrimental phenomena	Quantify, influence, or indicate occurrence of potentially (safety) detrimental phenomena <ul style="list-style-type: none"> that might compromise ability of system to meet safety-related requirements or conform with reference assumptions for safety assessment, and/or that are present in Nagra's FEP List and are clearly detrimental
Indirectly-determined parameters	Are needed for the evaluation of other key parameters that cannot be measured or monitored directly

*a parameter may fall into one or more of these categories

STEP 1: key, safety-relevant parameters

List of potentially relevant parameters

Reasons for relevance: apply filter

- Requirements and reference assumptions defined with this parameter
- Potentially detrimental phenomena quantified, influenced or indicated by this parameter
- Parameter is needed for the evaluation of other key parameters
- Other grounds

Parameter	Key
Hydraulic conductivity (Opalinus Clay)	Red dot
Hydraulic conductivity (operational tunnel EDZ/CDZ)	Blue dot, Green dot
Hydraulic conductivity (SF/HLW buffer)	Red dot
Hydraulic conductivity (SF/HLW emplacement room EDZ/CDZ)	Blue dot, Green dot
Ionic strength (Opalinus Clay porewater)	Red dot, Blue dot
Ionic strength (SF/HLW buffer porewater)	Blue dot
Liquid flow rate (emplacement room EDZ/CDZ)	Red dot, Blue dot
Liquid flow rate (inflow open tunnels)	
Liquid flow rate (operational tunnel EDZ/CDZ)	Red dot, Blue dot
Minimum radionuclide transport distance (host rock)	Red dot
Outer diameter (operational tunnels)	Blue dot
Outer diameter (SF/HLW emplacement rooms)	Red dot, Blue dot, Yellow dot
pH (Opalinus Clay porewater)	Red dot, Blue dot
pH (operations tunnel porewater)	
pH (SF/HLW buffer porewater)	Blue dot
Radial extent (operational tunnel EDZ/CDZ)	Blue dot, Green dot
Radial extent (SF/HLW emplacement room EDZ/CDZ)	Blue dot, Green dot
Radiation (general)	Red dot, Blue dot, Green dot, Yellow dot
Radiation dose (canister surface)	Red dot, Blue dot, Green dot
Radioactivity (SF/HLW buffer in gas phase)	Blue dot, Yellow dot
Saturation (backfilled operational tunnels)	Blue dot
Saturation (EDZ)	
Saturation (SF/HLW buffer)	Blue dot, Green dot
Seismic displacement/acceleration (host rock)	Red dot, Blue dot

- Requirement related to canister wall thickness
 - The wall thickness should ensure long-term structural integrity and that the radiation dose rate at the canister outer surface is < 1000 mSv/hr in order to preclude radiation-induced corrosion.*
- Requirement on the radiation dose itself
 - Radiation dose at the canister surface after leading and sealing of the canister should be less than 1000 mSv/h to avoid radiation-induced corrosion.*

STEP 2: Prioritisation

- Prioritisation based on
 - likelihood of (and uncertainty in) changes to parameter value during monitoring period
 - safety-relevance of such changes

Priority	Basis	Examples
High priority	Significant changes expected during the pre-closure monitoring period (especially if there are significant uncertainties associated with those changes)	<ul style="list-style-type: none"> • Near-field temperature • Near-field pore pressures
Secondary priority	Significant changes not expected, but cannot be completely excluded	<ul style="list-style-type: none"> • Geometry - underground structures
None	Significant changes in a parameter can be confidently ruled out or are irrelevant to safety	<ul style="list-style-type: none"> • Thickness of uncorroded canister wall

Input to STEP 3

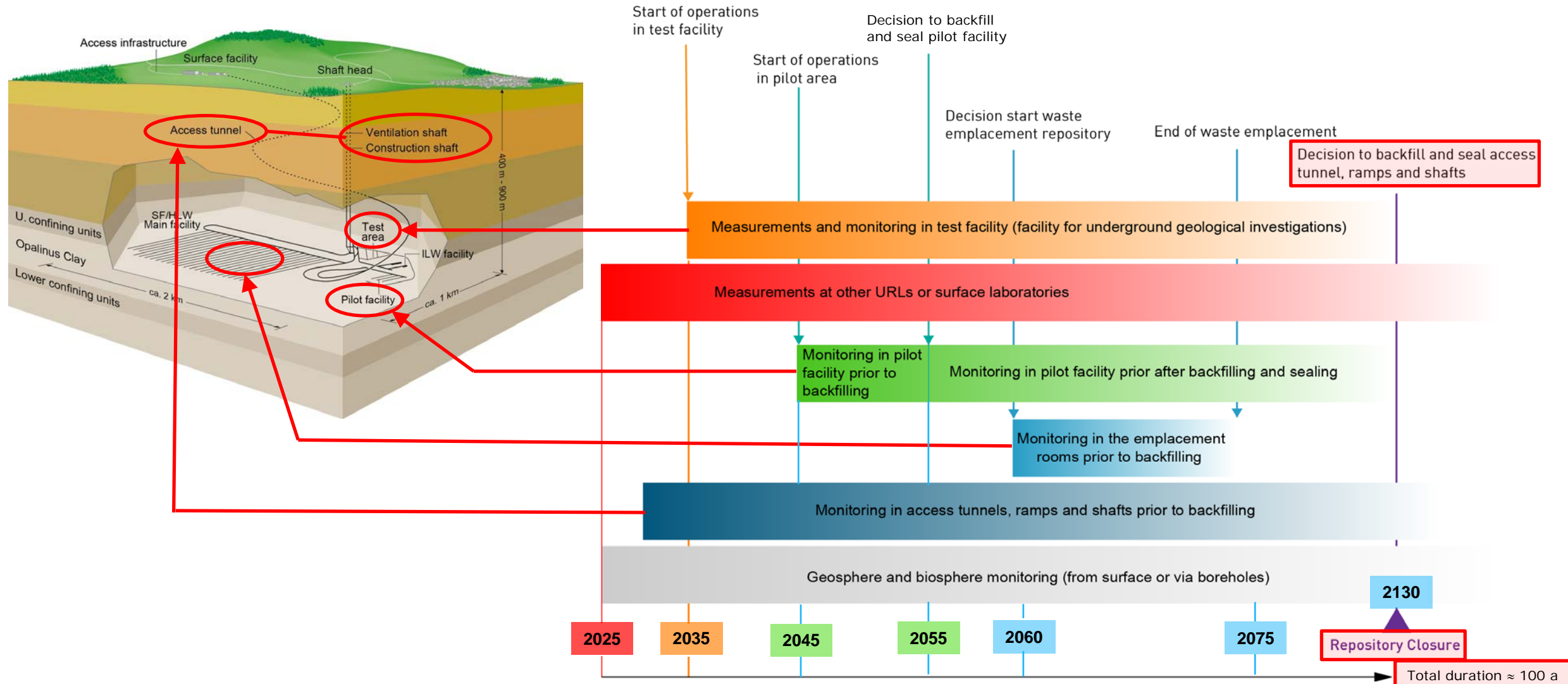
STEP 3: technical feasibility of monitoring

High- and secondary-priority parameters from STEP 2

Amenable to monitoring in practice?

Yes	Examples		→ Determine how, where and when to monitor →
	<ul style="list-style-type: none"> Fluid (pore) pressure; pH porewater Temperature 		
No	Reason	Examples	Park
	Technology development needed	<ul style="list-style-type: none"> Far-field stress changes; reactivation of faults 	
	Parameters measured once or infrequently	<ul style="list-style-type: none"> Porewater composition 	Park
	Indirectly determined parameters	<ul style="list-style-type: none"> Heat fluxes EDZ permeability 	→ Feedback to STEP 1

Tentative schedule and opportunities for measurements/monitoring



Example of the assessment of a potential monitoring technology

pH probe

TRL 9

Acoustic sensing
Eh probe
Electrical conductivity probe
Evapometer
Extensometer
FDR
Fibre optics for distributed pore pressure
Fibre optics for strain
Fibre optics for temperature
Flowmeter
Gamma counter
Gas sampling and inline spectrometry
Gas threshold pressure test
Geiger counter
Humidity sensor capacitive
Hydraulic testing
Ion selective probe
LVDT displacement sensor
Mechanical/total stress pressure sensor
Mini ventilation tests
Modular mini packer systems (MMPS)
pH probe
Piezometer / Pore pressure sensor
Porewater extraction and laboratory analysis
Psychrometers
Radar (geophysical)
RTDS: PT100/PT1000
Seismics (Geophysical)
Strain meter
TDR

Details of selected technology

Delete this technology or edit parameters

pH probe

Need for maintenance or repeated calibration

Yes

Data transmission (choose from drop-down list)

Wired

Level of readiness (choose from drop-down list)

TRL9: Actual system proven in operational environment

Parameters that can be monitored with this technology

pH (Opalinus Clay porewater)

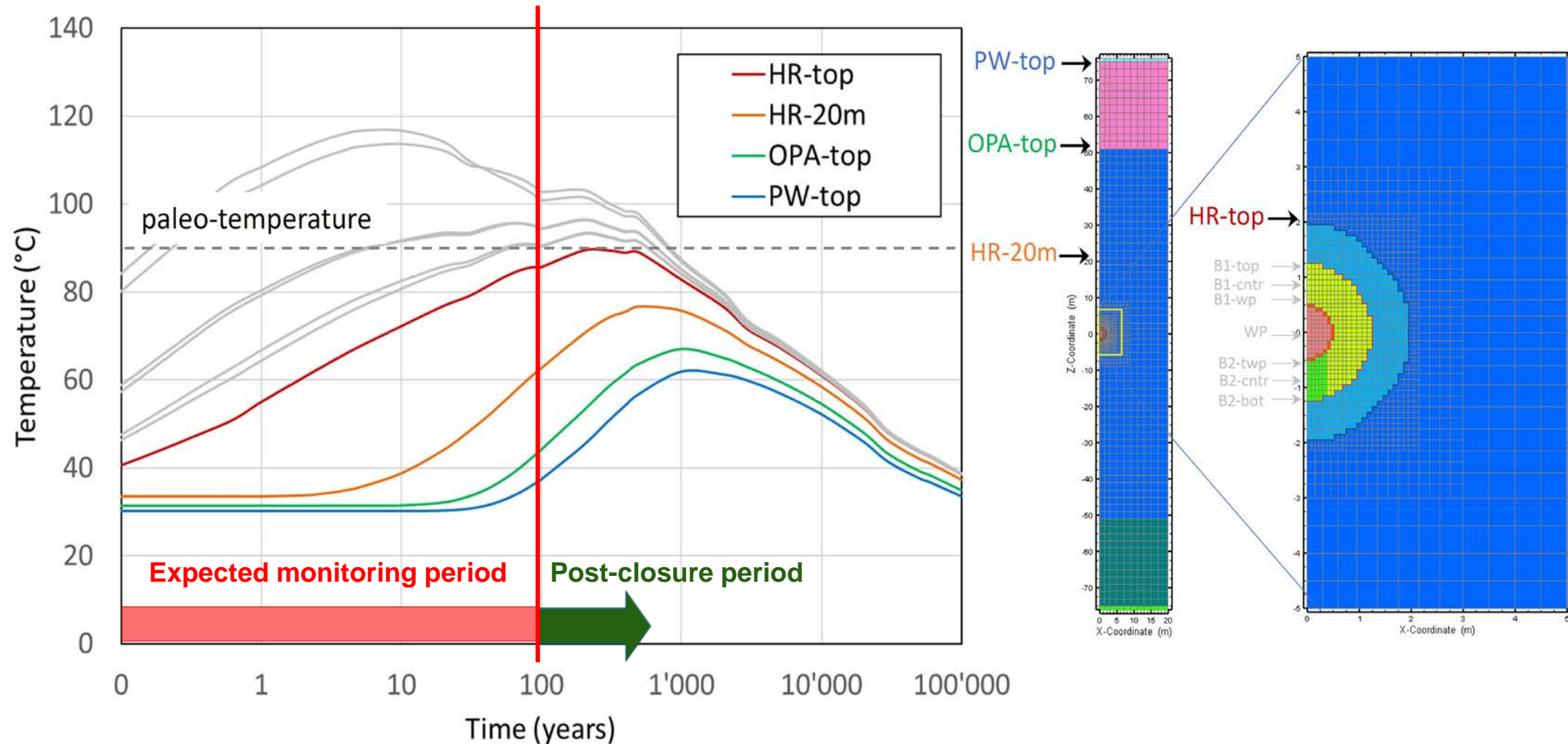
pH (SF/HLW buffer porewater)

pH (operations tunnel porewater)

Comments

STEP 4: Models and safety-relevant criteria exist?

- Example of temperature evolution



STEP 5: Overall rationale for monitoring

	Prioritisation	
	Secondary	High
Currently with criteria	4	2*
No criteria	16	14

Rationale for monitoring

1. Build confidence that each barrier meets its requirements and conforms with reference assumptions

2. Build confidence that potentially detrimental phenomena do not compromise safety

- a. Confidence in general understanding of the phenomena
- b. Confidence in input parameters for modelling the phenomena
- c. Confidence in model predictions, including adherence to criteria

3. Build confidence in the parameter values used for the evaluation of other key parameters

4. Other reasons to monitor this parameter

- a. Support decision making (e.g. when to backfill a section of repository)
- b. Stakeholder demands/reassurance
- c. Other grounds

Set as rationale?

Yes: high priority

Set as rationale?

Yes: high priority

Yes: high priority

Set as rationale?

Yes: high priority

No

No

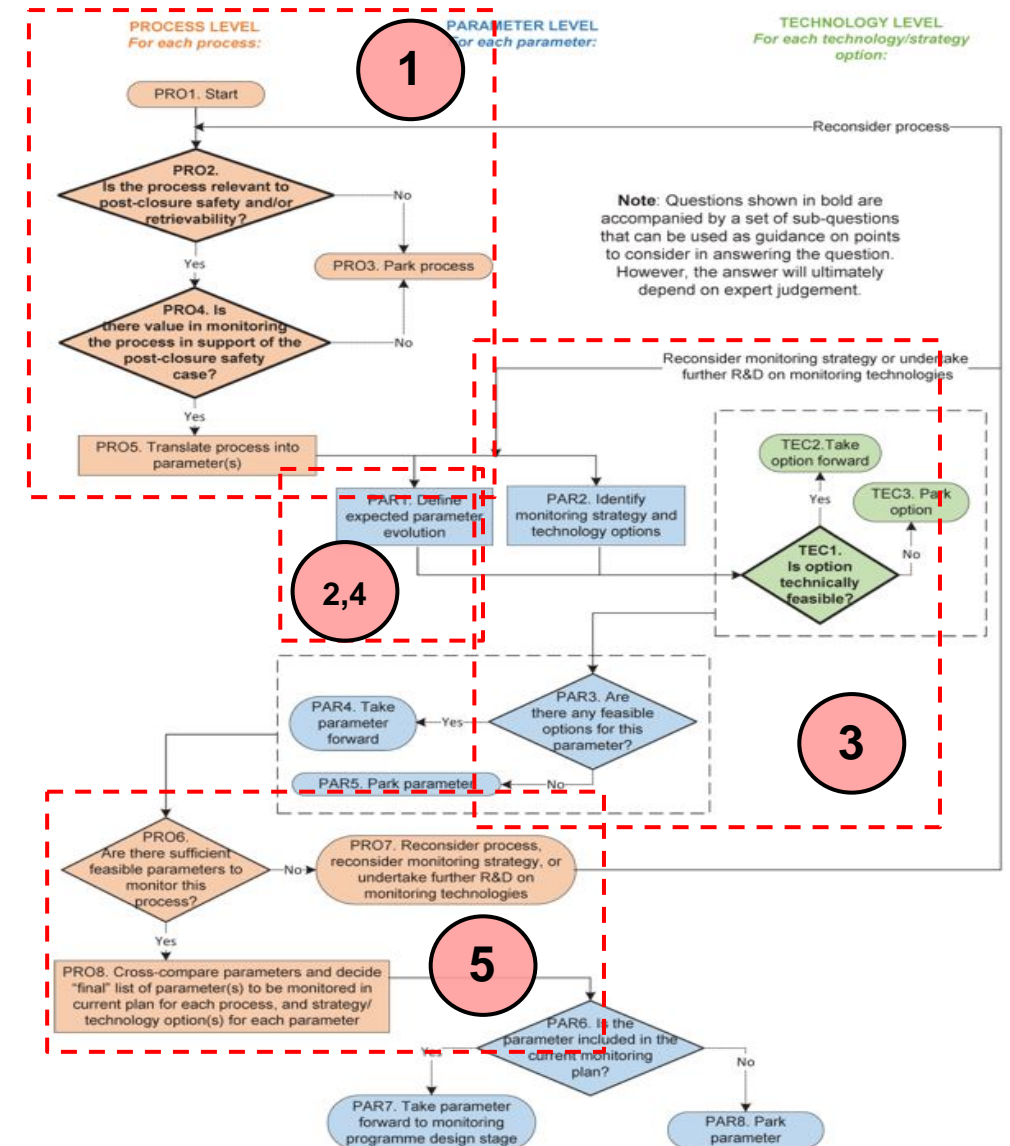
*Fluid pressure (Opalinus Clay) and temperature (Opalinus Clay)

Comparison with Modern2020 Screening Methodology

- Each of the steps of Nagra's methodology can be mapped onto the generic Modern2020 Screening Methodology; a few differences noted:

Modern2020	Nagra
Translates processes into parameters	Also includes parameters that define requirements and model assumptions
-	Prioritises parameters on the basis of significant or relevant changes
-	Acknowledges some parameters are evaluated indirectly from other (monitored) parameters
Includes development of monitoring plan and programme	-*

*Work currently in progress



**Thank you for your
attention!**

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