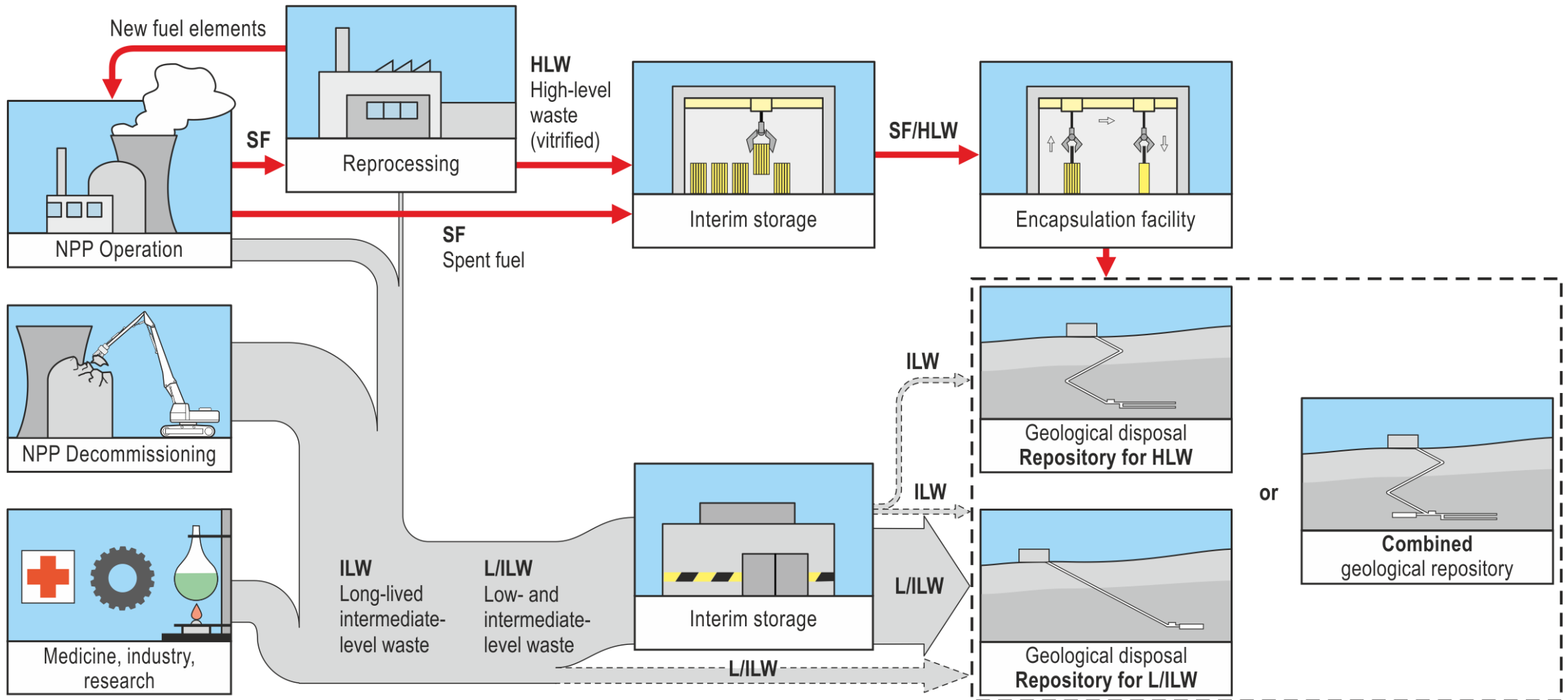


Site characterisation in the final stage of selecting the site in sedimentary clay rock in Switzerland

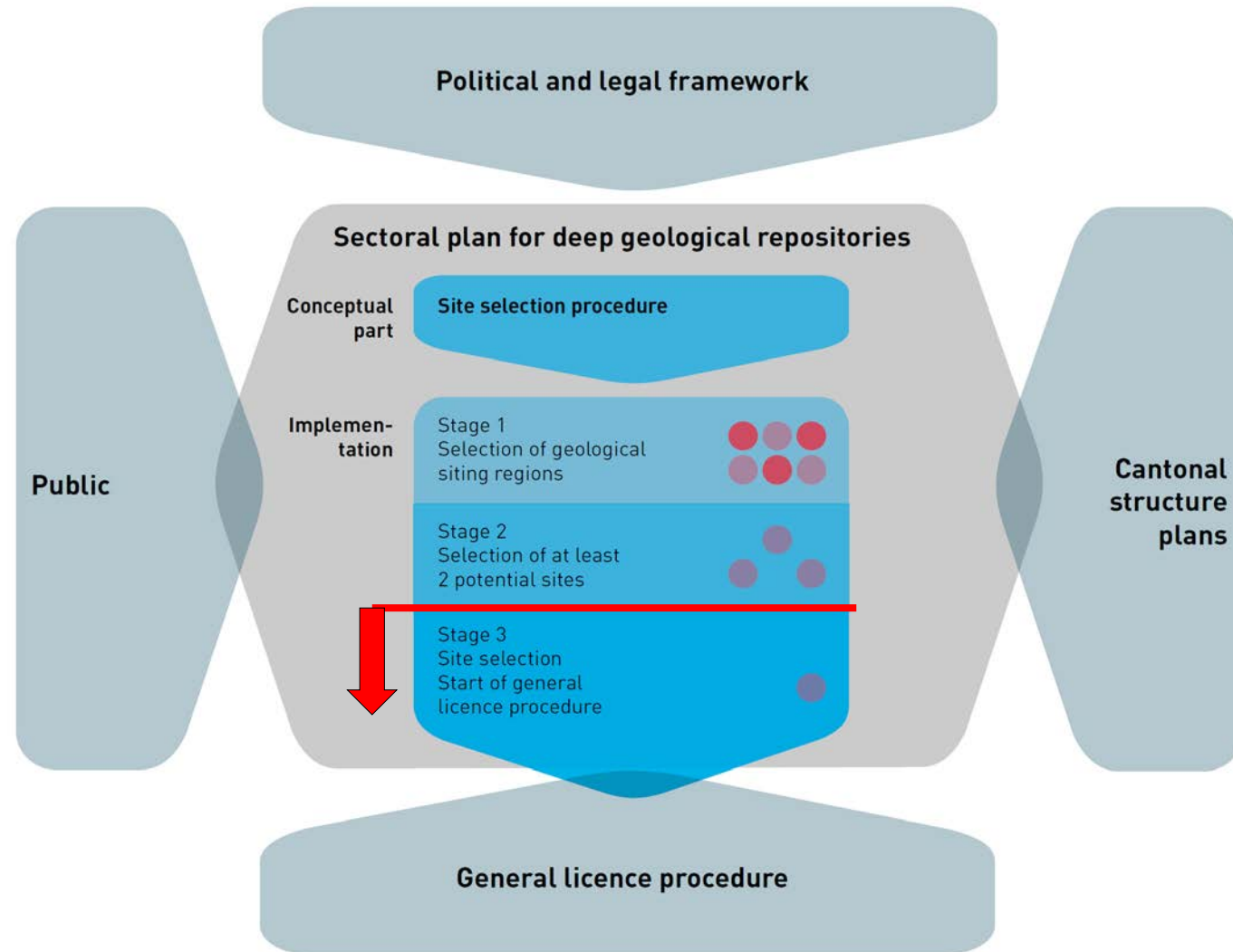
Bernd Frieg

nagra.

Swiss waste management concept

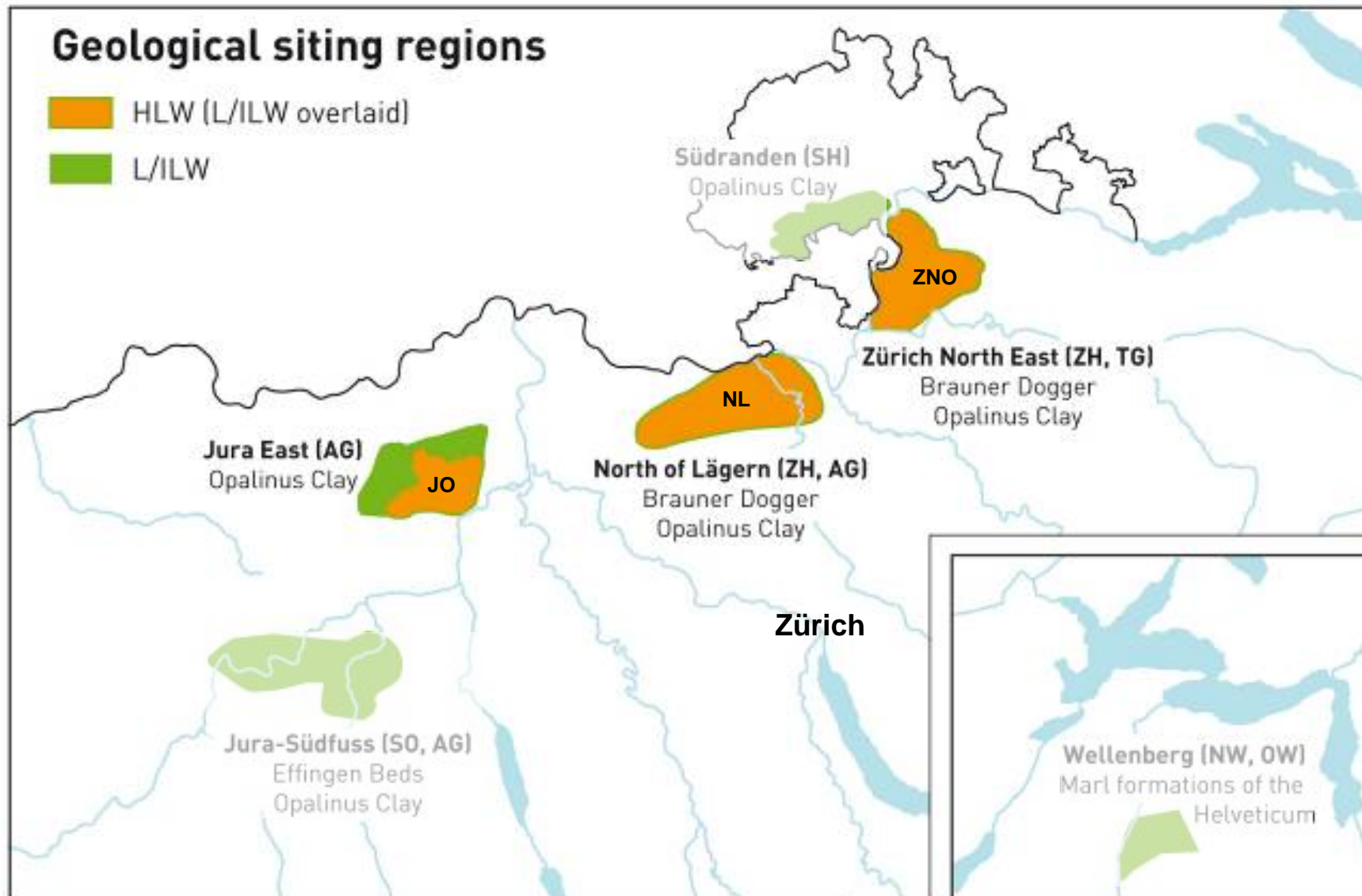


Sectoral Plan – 3 stages towards site selection



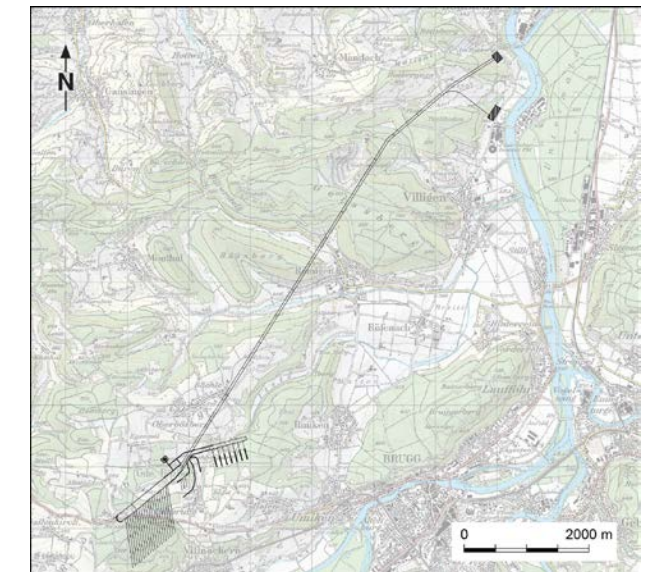
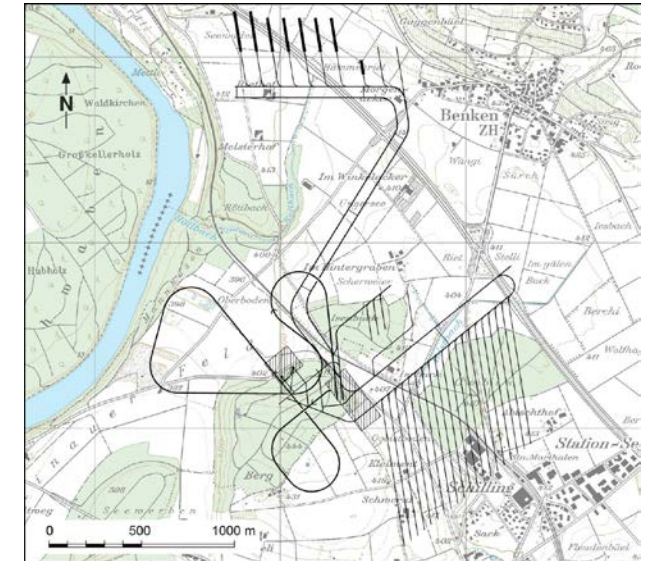
Stage 1	2008 - 2011
Stage 2	2012 - 2018
Stage 3	~ 6 years

Proposed siting regions (end of SGT E2 (stage 2))



Combined repository or two single repositories: Decision steps

- With the Stage 2 available data, the disposal perimeters at each site are large enough to also accommodate both repositories (**combined repository**)
- For each site, variants for a HLW-repository, a LLW-repository or a combined repository are being developed
- Based on the **results** from the **Stage 3 investigations** and considering the **safety and engineering feasibility criteria**:
 - the preferred site for the **HLW-repository** will be determined first
 - in a second step it will be assessed if there is still enough volume to locate the **LLW-repository** at the same site
 - if yes, the site will be proposed for a **combined repository**



Example of variants for combined repositories (ref. Cost Study 2016)

Existing investigations (end of SGT E2 (stage 2))



Deep boreholes

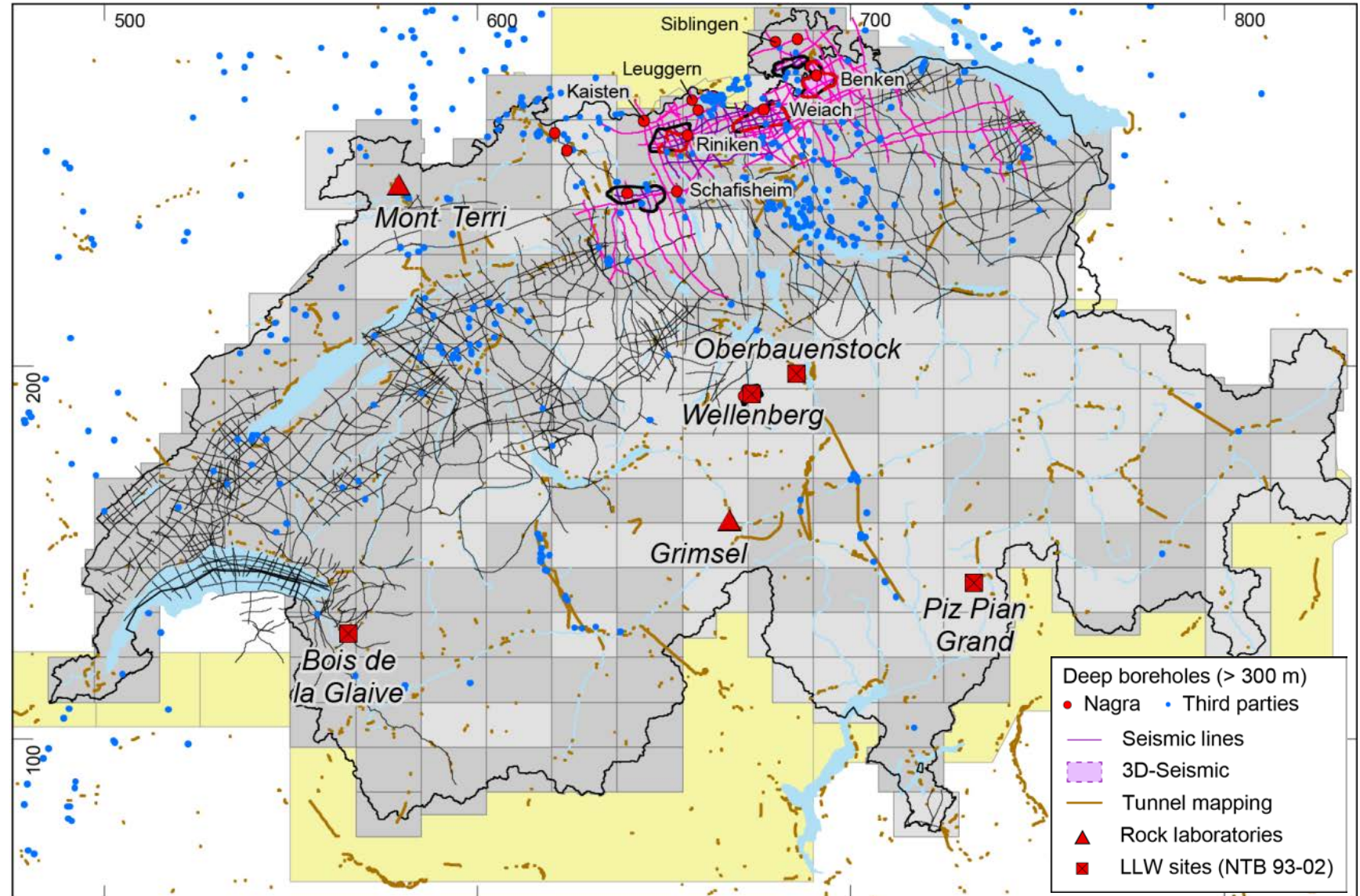
Seismic surveys



Mont Terri Project



Grimsel Test Site



Geological mapping & sampling



e.g. for dating
quaternary sediments



Exploration concepts (until the end of SGT E3 (stage 3))

nagra.

Arbeitsbericht NAB 14-83

**Konzepte der
Standortuntersuchungen für
SGT Etappe 3**

Dezember 2014

Nagra

Nationale Genossenschaft
für die Lagerung
radioaktiver Abfälle

Hardstrasse 73
CH-5430 Wettingen
Telefon 056-437 11 11
www.nagra.ch

nagra.

Arbeitsbericht NAB 16-28

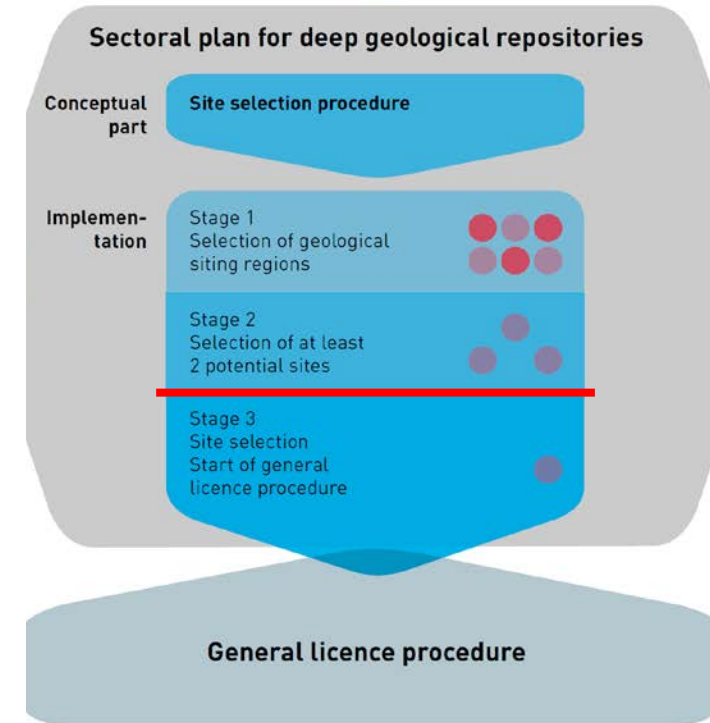
**Konzepte der Standortunter-
suchungen für SGT Etappe 3 –
Nördlich Lägern**

April 2016

Nagra

Nationale Genossenschaft
für die Lagerung
radioaktiver Abfälle

Hardstrasse 73
Postfach 280
5430 Wettingen
Telefon 056-437 11 11
www.nagra.ch



Stage 1	2008 - 2011
Stage 2	2012 - 2018
Stage 3	~ 6 years

Planning products

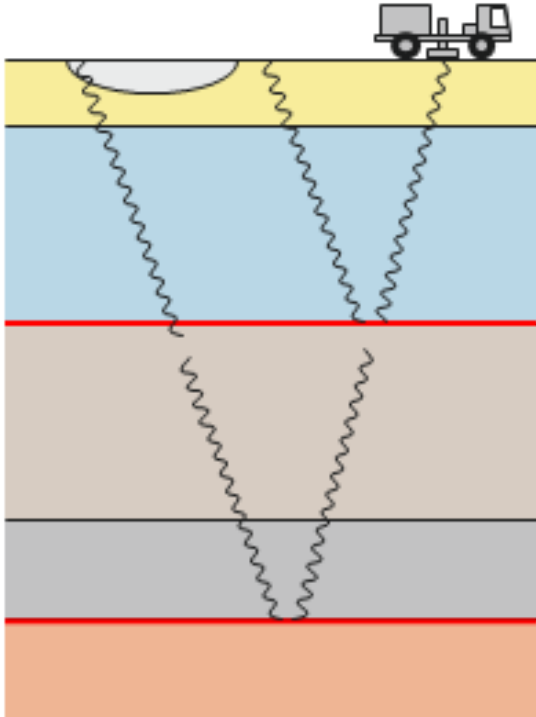
- **Site investigations strategy** (all phases and all sites update for each phase)
 - Aims per phase («identify / confirm / proof potential to construct safe repository»)
 - Investigations (desk study, airborne surveys, ground surveys, drilling, underground labs)
 - Key products and level of detail (see legal framework)
- **Site investigation concepts** (per phase and per site) → regulator
 - Geology
 - Phase specific aims
 - Breakdown of aims to individual methods
- **Survey / campaign concepts** where necessary
 - *2D, 3D-Seismics: not done (target description only)*
 - *shallow drilling: not done (target description only)*
 - deep drilling: planning report including
 - breakdown of aims to drilling sites
 - Scenarios for different outcomes
- **Drilling applications** (invasive investigations require licensing): catalog of investigations and drill paths / site → licensing authority
- **Drill site work programs** (for authorisation by regulator): selected methods / investigations per section → regulator



Key features– Stage 3 investigations

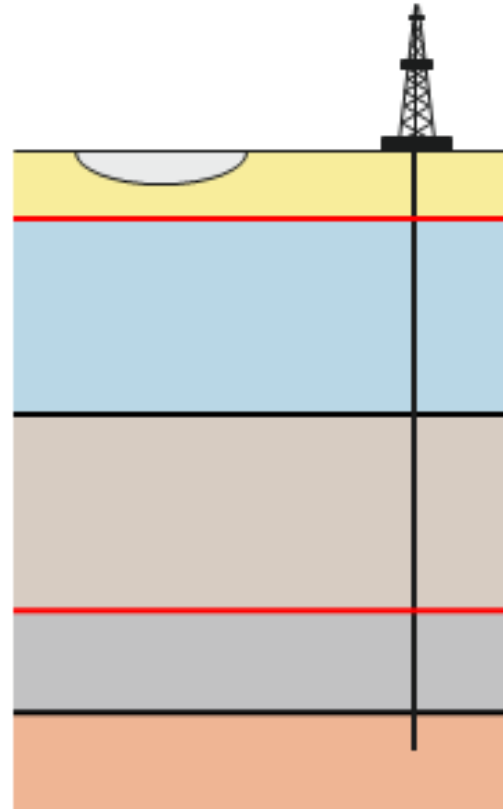
No.	Feature	Mainly applicable to		Investigations in Stage 3
		HLW	L/ILW	
M01	Higher fault density in parts of the disposal perimeter and shearing in the host rock due to thrusting from the Alps	X	(X)	3D seismics, boreholes for confirming the fault inventory
M02	Zones with increased density of sub-vertical faults	(X)	(X)	3D seismics
M03	Zones with increased fault density in the vicinity of local compressive structures	X	X	3D seismics, possibly boreholes
M04	Confirmation of depth of the containment-providing rock zone	X	X	3D seismics, confirmation of depth using boreholes
M05	Significance of overdeepened gullies (channels) for the erosion scenarios	X	X	Literature studies, shallow boreholes, 3D seismics with deep boreholes
M06	Thickness and quality of the upper confining units of the Opalinus Clay, particularly the lower parts of the 'Brauner Dogger'	X	X	Boreholes for confirmation, 3D seismics, supplementary studies
M07	Thickness and quality of the host rock, particularly with respect to construction engineering aspects	X	X	Boreholes for confirmation, 3D seismics
M08	Basement geology with regard to fault reactivation and conflicts of use	X	X	Boreholes, 3D seismics, gravimetry, geoelectrics

Geological investigations in Stage 3



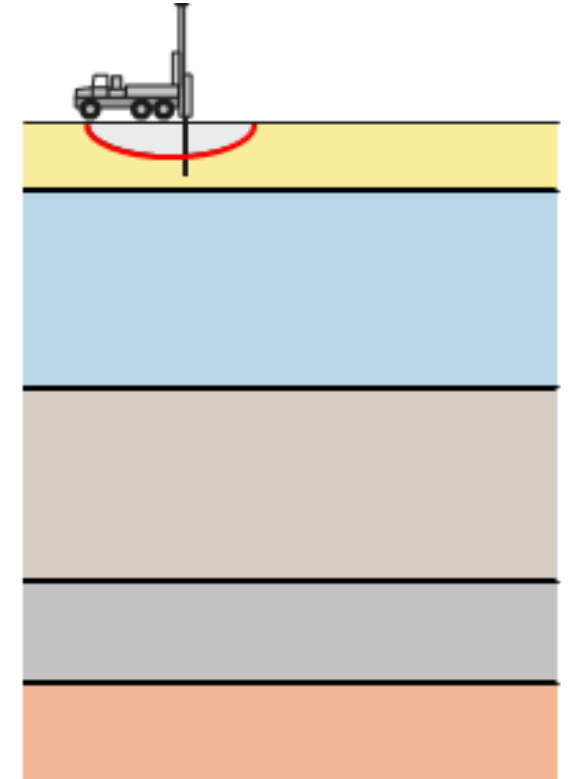
3D-Seismic

- Geological model
- Available volume
→ Spatial extent



Deep boreholes

- Rock properties
- Seismic calibration
- Available volume
→ Vertical extent

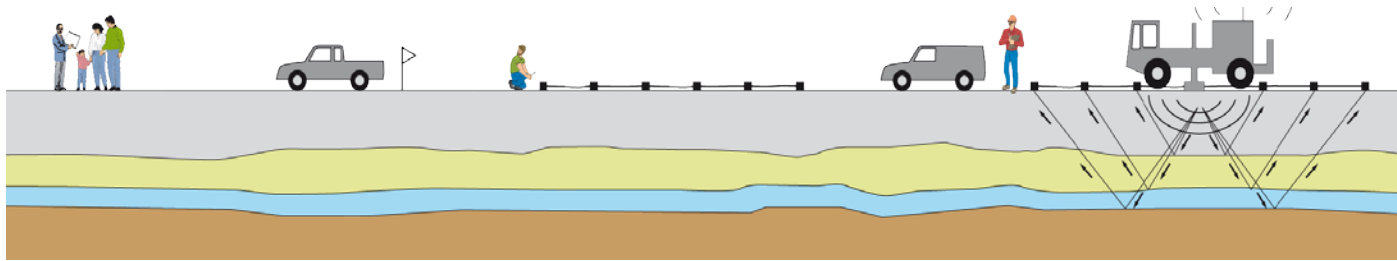
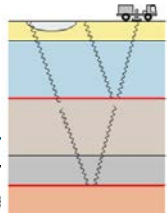
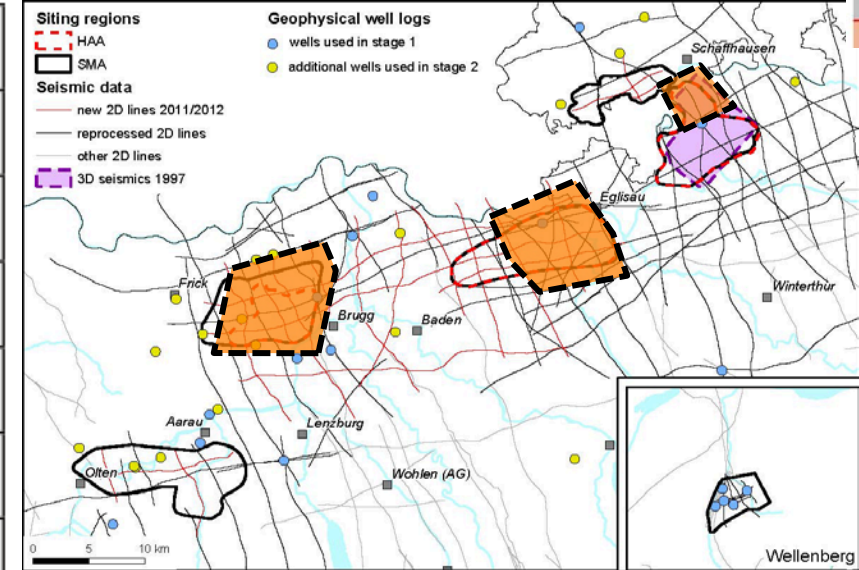


Quaternary investigations

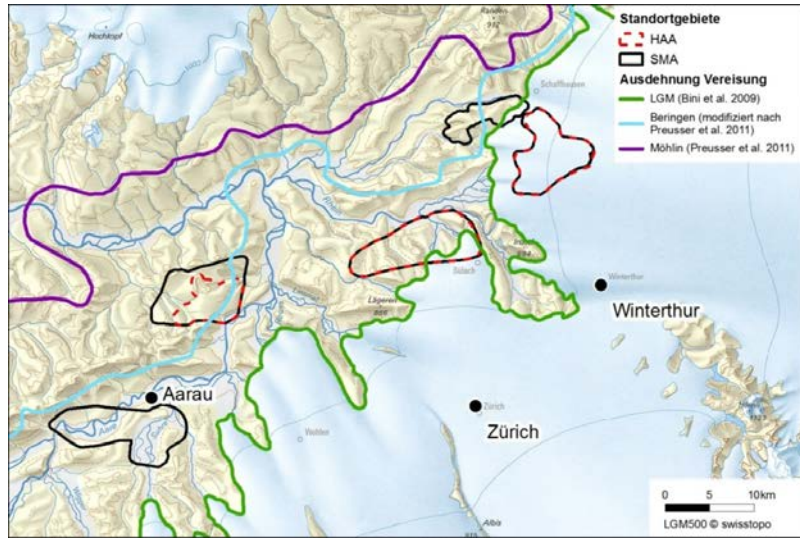
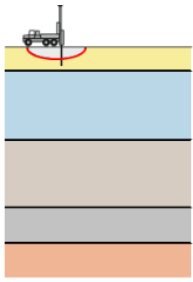
- Basis for derivation
of future erosion
scenarios

3D-seismic campaign 2015 - 2017

Parameter	Jura Ost	Zürich Nordost	Nördlich Lägern
Area [km ²]	92.6	18.3	91.6
Land owners contacted	1'624	565	1'810
Land owners giving their permission	1'609 (99 %)	548 (97 %)	1'750 (97 %)
Communities	27	9	17
Measurement days	97	17	77
Person days	12'730	2'400	13'500
Kilometers driven	410'000	100'000	600'000
Shot points (vibration vehicles/explosives)	16'315 / 3'409	3'319 / 407	14'937 / 2'392
Measurements points	25'742	5'109	20'258

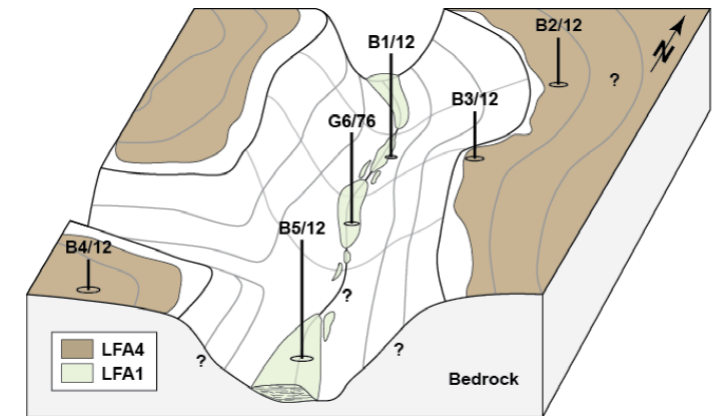
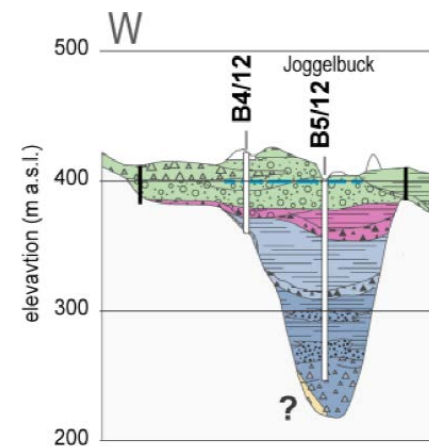
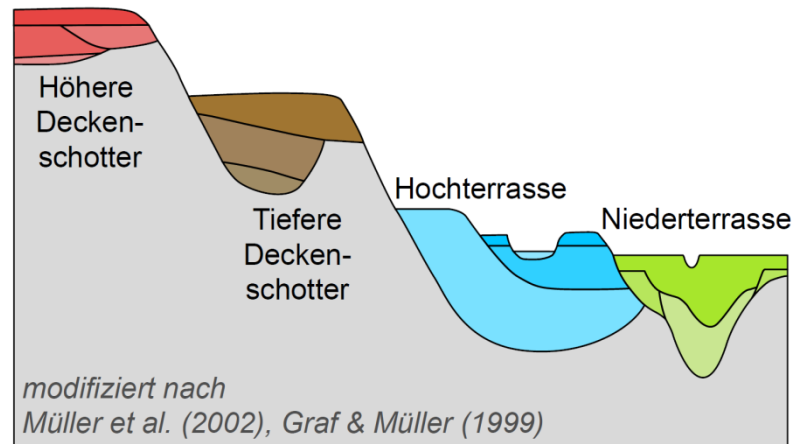


Quaternary investigations

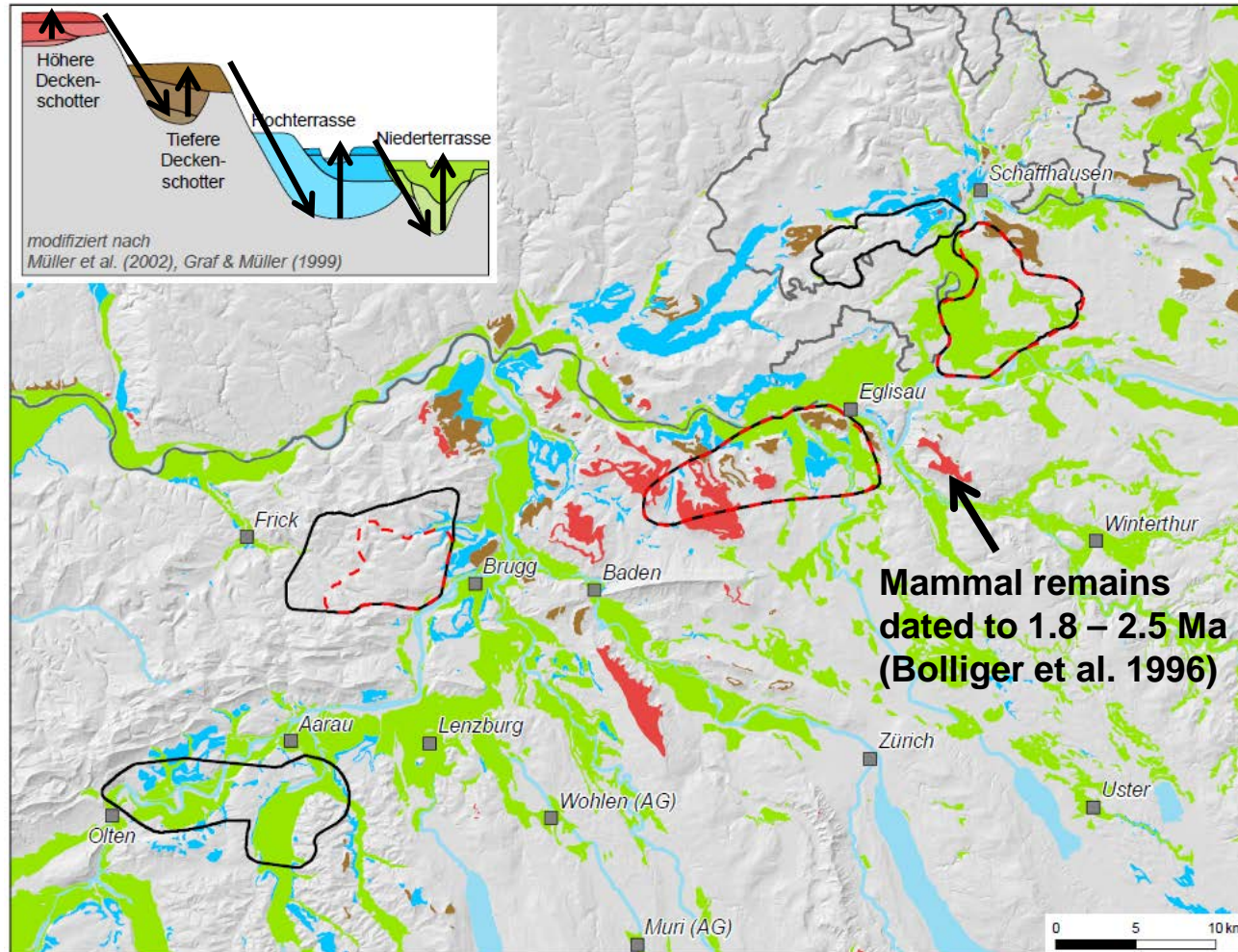


Field investigations

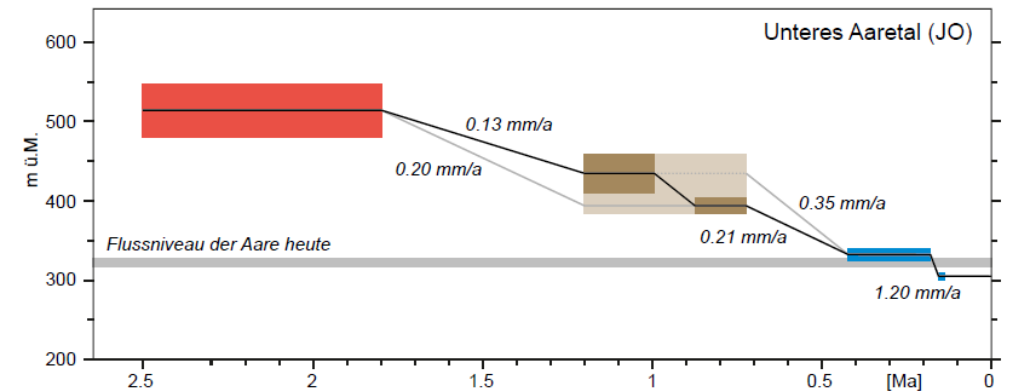
- Drilling into **quaternary** deposits to investigate erosion processes (dating sediments)
- **First drilling started in March 2018**, permit applications for 3 additional drillings undergone public consultation and in the licensing stage by DETEC



Longterm erosion and uplift rates from fluvial terraces



- Fluvial terraces: archives for reconstruction of base level evolution
- Periods of consideration:
 - Past approx. 2 mio yrs
 - Future approx. 1 mio yrs



Total fluvial erosion

last 2 mio yrs 210 m

last 1 mio yrs 130 m

last 0.4 mio yrs 30 m

Average erosion rates

last 2 mio yrs 0.11 m/a

last 1 mio yrs 0.13 m/a

last 0.4 mio yrs 0.08 m/a

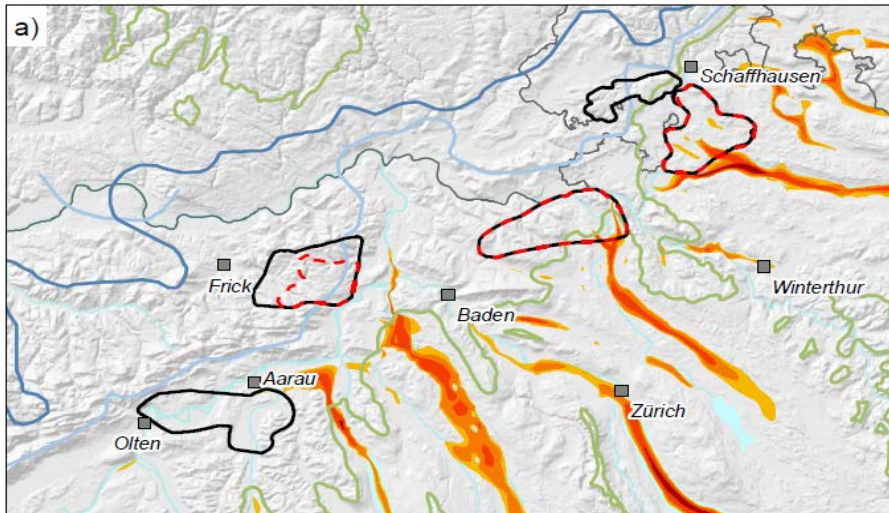
Estimation of repository depth: Stage 3 approach

Fluvial erosion



Glacial erosion

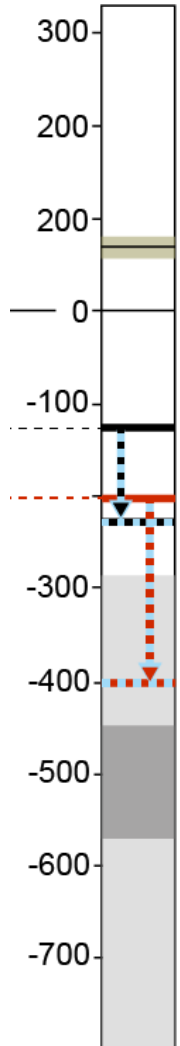
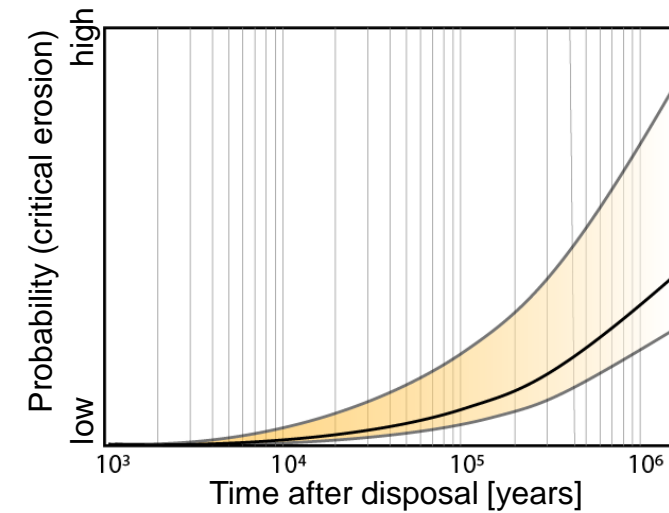
(→ significant overdeepenings)



Climate scenarios

Bayesian analysis
(stochastic)

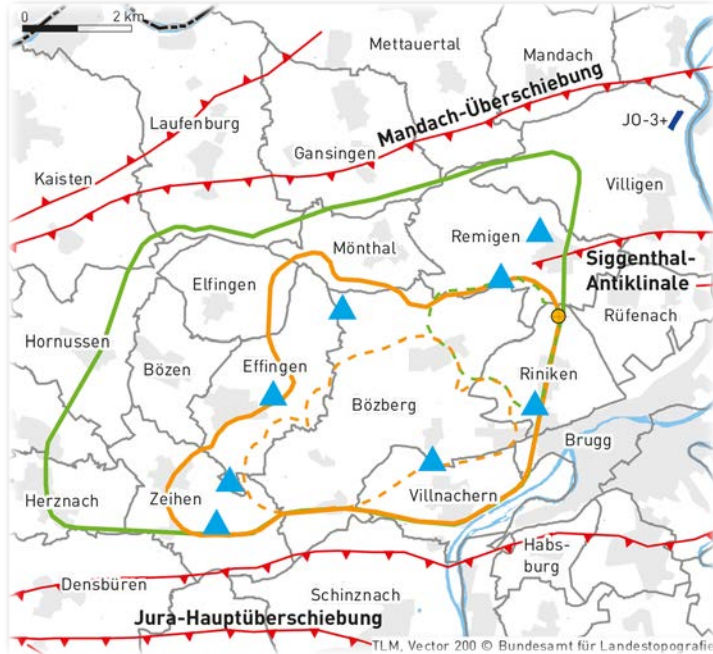
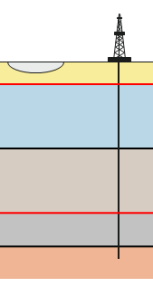
What is the probability of a **critical erosion volume** at site X and at time Y?



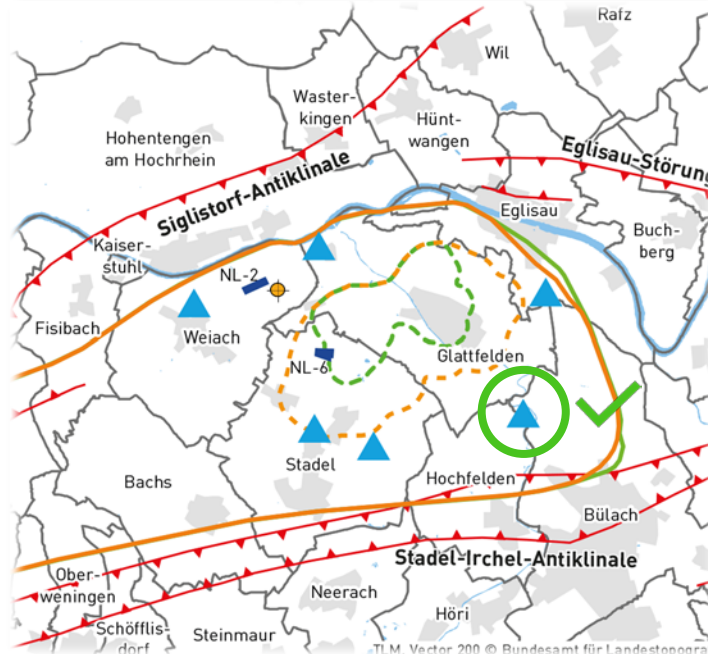
Site investigation concepts – underlying strategy

- **3D-Seismics:** include tectonic context
- **Deep drilling:** go for the boring geology (proof suitability) avoid complexities
- **Drilling applications:** 2 years for a license (plus planning / negotiations and optional legal procedures); 3D-seismics: 1 year preparation (no license required) 1 year processing and interpretation; in-sequence work: 4 years min. to locate drill sites
 - → locate drill sites based on 2D-results (on lines)
 - → use approximate locations to distribute targets, built in soft links (avoid to be cornered)
- **Effort vs. flexibility? Flexibility!** 6 – 8 drilling applications / site with 3-4 directions each. **Invest** in preparation work and negotiations (licensing authority, regulator, cantons, communities, land owners) → **React quickly** to investigation results and availability of drilling licenses

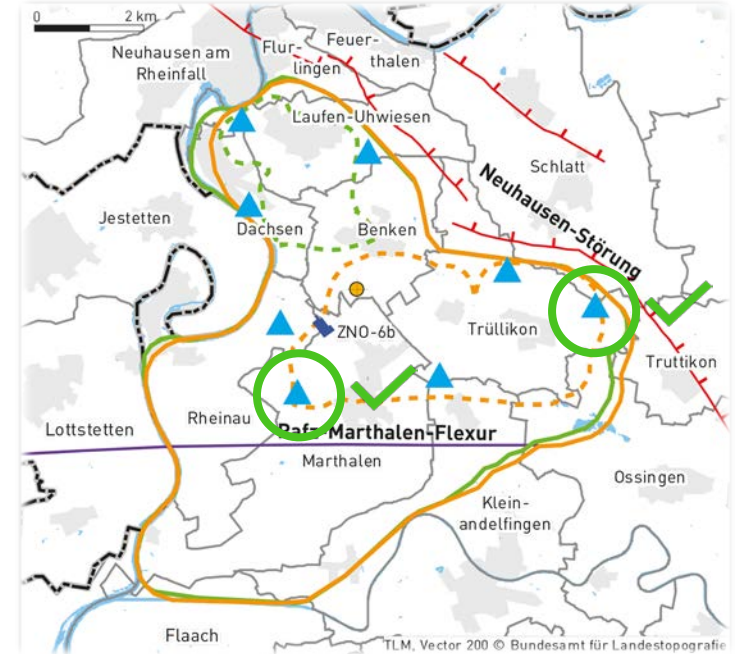
Deep borehole investigations



Jura Ost



Nördlich Lägern



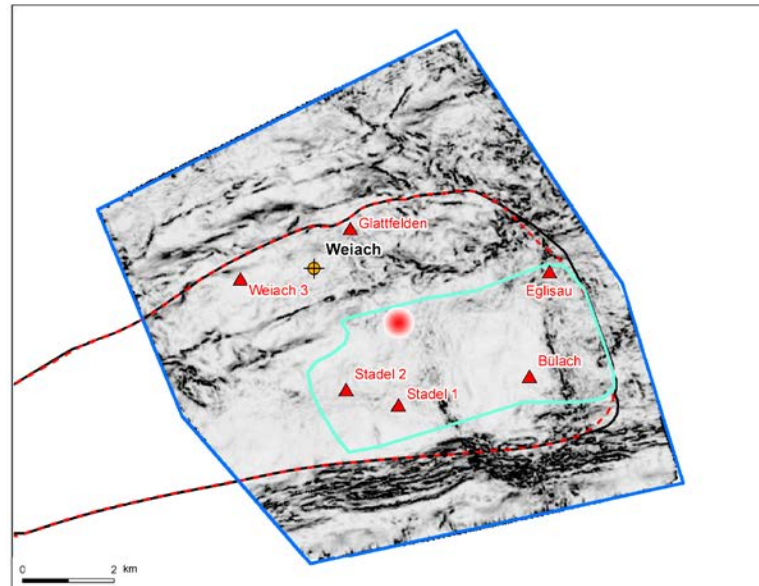
Zürich Nordost

	# boreholes	ENSI approval	Fed. Gov. approval
Jura Ost	8	11/2017	pending
Nördlich Lägern	6	3/2018	1/6 (Aug. 18)
Zürich Nordost	8	1/2017	2/8 (Aug. 18)

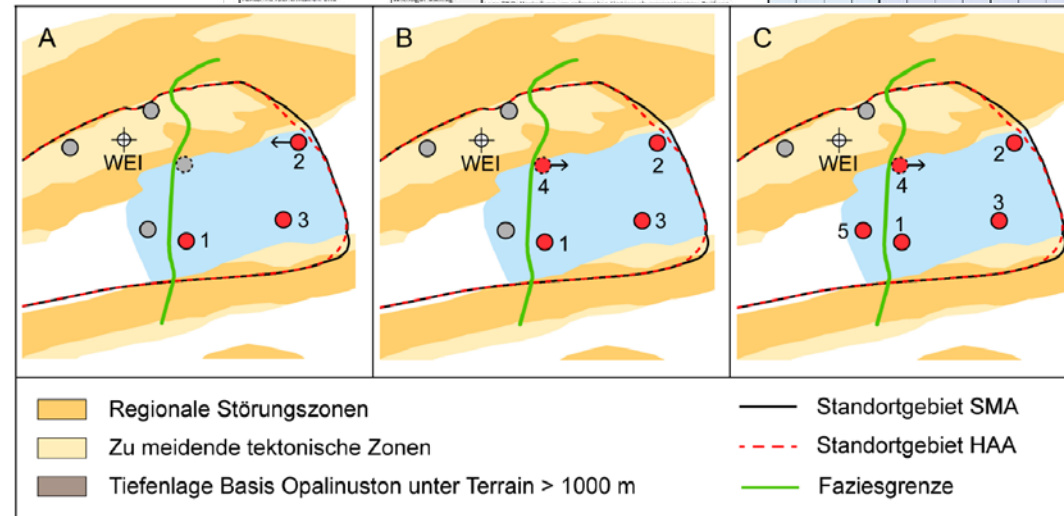
- Permits from the Federal Government sequential starting **August 2018**
- Borehole site preparation in late Fall 2018
- **Start** of drilling operations at selected sites in **2019**

Survey / campaign concept (drilling campaign)

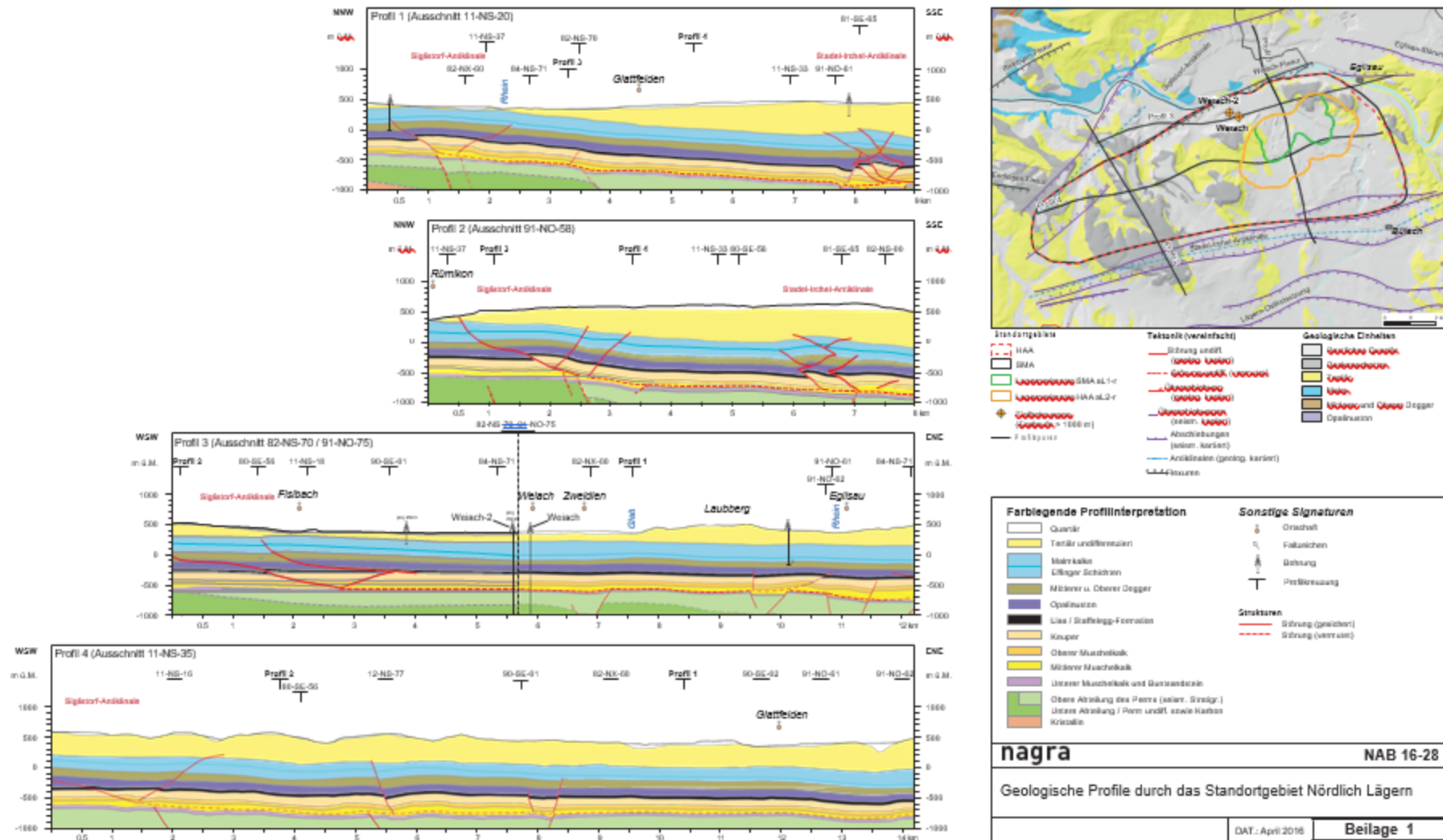
- Identification of most promising areas within siting regions
- Updated and refined targets
- Discussion of drilling sequence → base for discussion with regulator



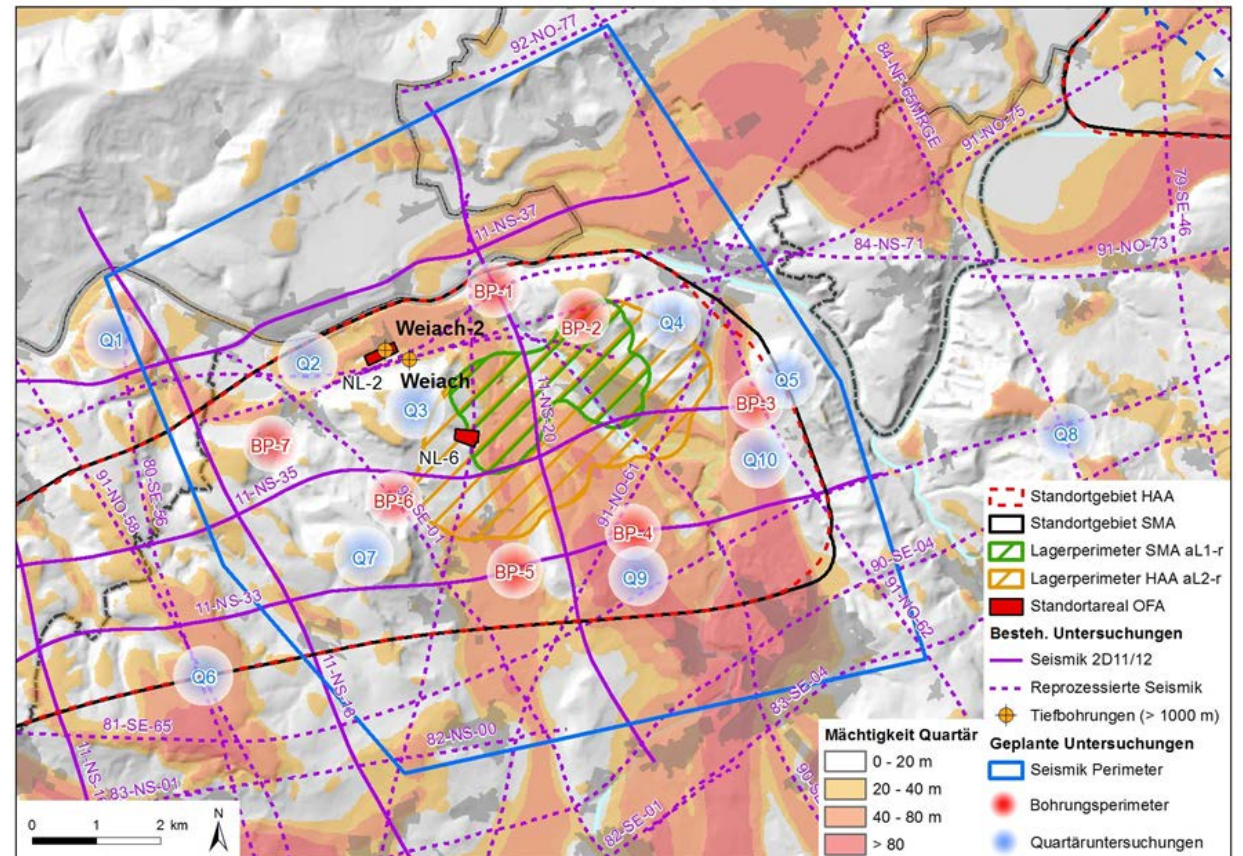
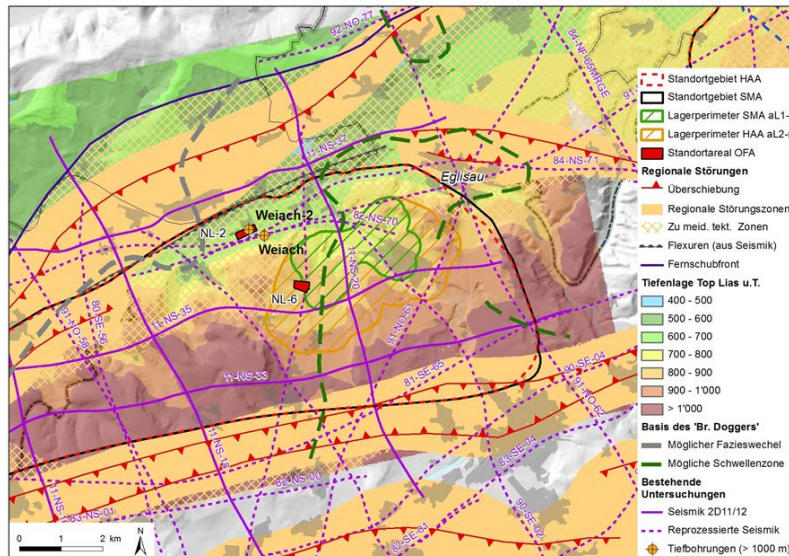
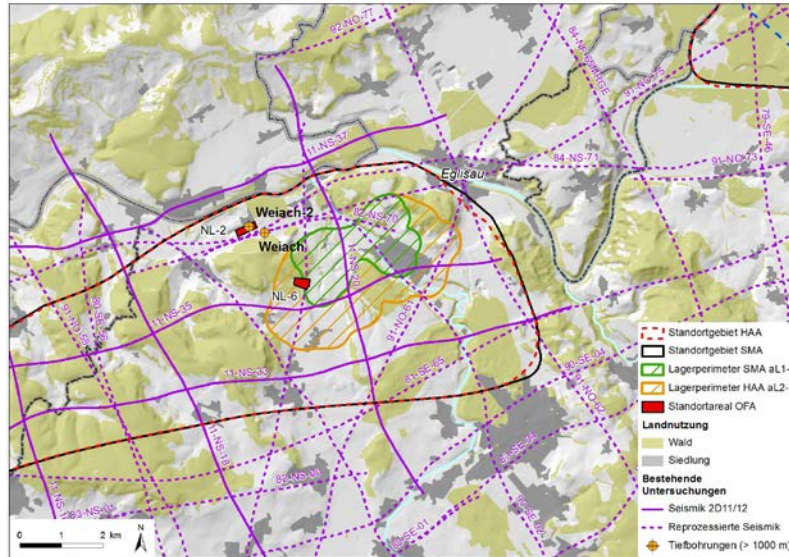
Thema	Unspezifischer Beitrag IBO für Standard-Untersuchung	spezifischer Ziele / Anforderungen an Bohrstandorte und Arbeitsprogramme	Tiefbohrbohrungen						Tiefbohrbohrungen						Tiefbohrbohrungen					
			Kern/Bohrbohren	LOGS	In situ Tests	LZ-Monitor	Kern/Bohrbohren	LOGS	In situ Tests	LZ-Monitor	Kern/Bohrbohren	LOGS	In situ Tests	LZ-Monitor	LOGS	LZ-Monitor				
Allgemeine geologische Verhältnisse (Schichtmächtigkeit, Lithostratigraphische Verhältnisse, Tektonik) Ziel: Ertüchtigung des Bohrstandortes und Aufklärung des Schichtaufbaus, Reduktion der Unsicherheiten hinsichtlich der Lithologie.	Zentraler Beitrag Relevant für diverse Aspekte (z.B. Bohrstandortwahl, Bohrtechnik, Erdoberfläche)	Lage IBO: Verteilung um relevanten Untersuchungsperimeter. Relevante Schichtmächtigkeiten: Top Terrain bis 20 m unter Basis Massivum in beiden Richtungen; subvertikale Störungen insbesondere in Schräglage und vertikaler Richtung.	K/C	VSP, PET			K/C	VSP, PET			K/C	VSP, PET			K/C	VSP, PET	E/C	VSP, PET	K	PET
Uthorizontale Abgrenzung und Habitus Ziel: Datenbasis zur lithologischen Abgrenzung und Charakterisierung der verschiedenen Faziesheiten und deren Übergänge im weitestmöglichen Bereich des Bohrstandortes; Prüfung lithologischer Korrelationen zwischen Bohrungen; Identifikation möglicher Faziesübergänge.	Zentraler Beitrag Relevant für diverse Aspekte (z.B. Bohrstandortwahl, Bohrtechnik)	Lage IBO: Verteilung um relevanten Untersuchungsperimeter. Relevante Schichtmächtigkeiten: Fokus Top Wöllegg-Fm. bis Schichtmächtigkeit 10 m; in Schräglagen Fokus bis 100 m.	K/C	PET			K	PET			K	PET			K	PET	K	PET		
Tektonische Identifikation und Beitrag		Ziel: Prüfung möglicher Aufschaltungen im weitestmöglichen Bereich.																		



NL – SDM – Geological profiles



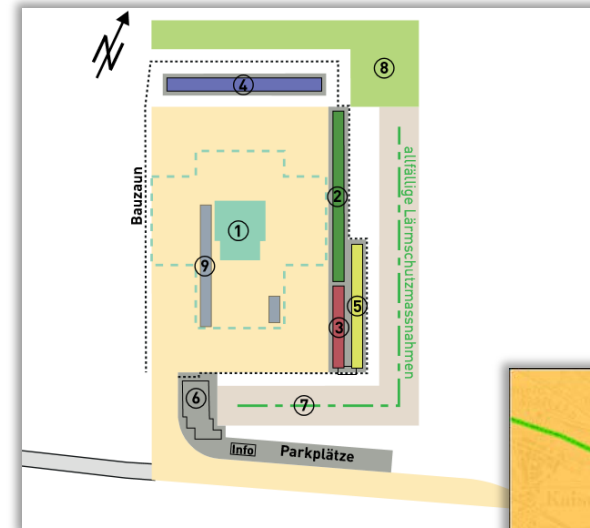
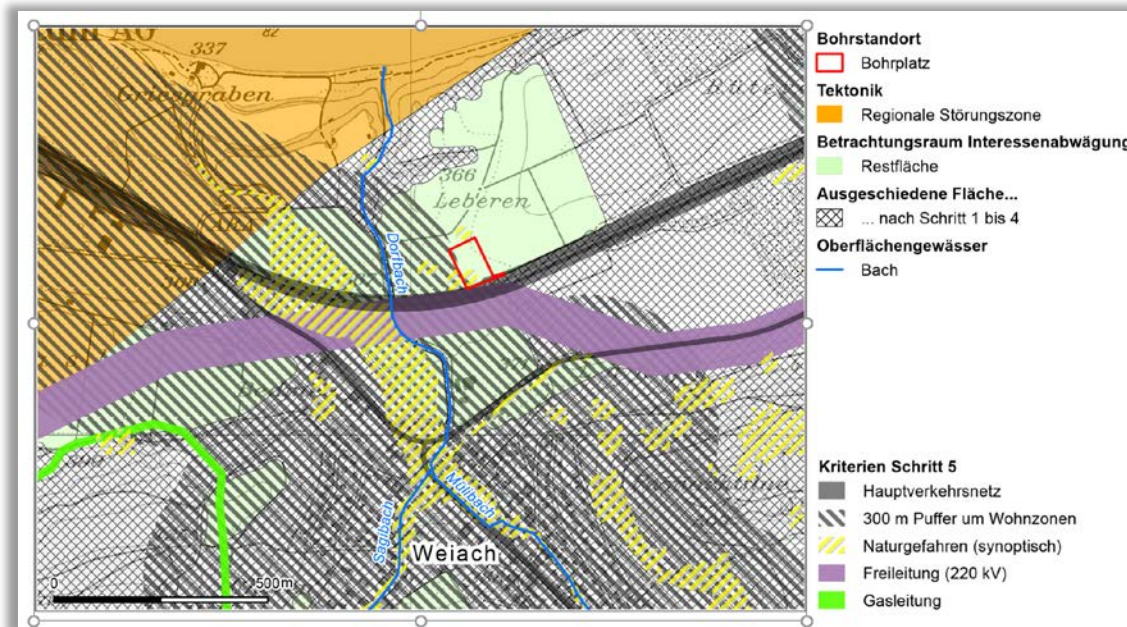
Nordlich Lägeren - available information (SDM)



Deep and quaternary borehole locations

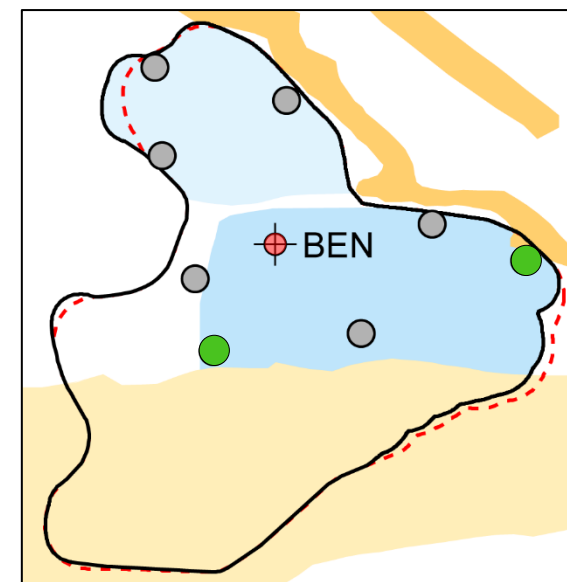
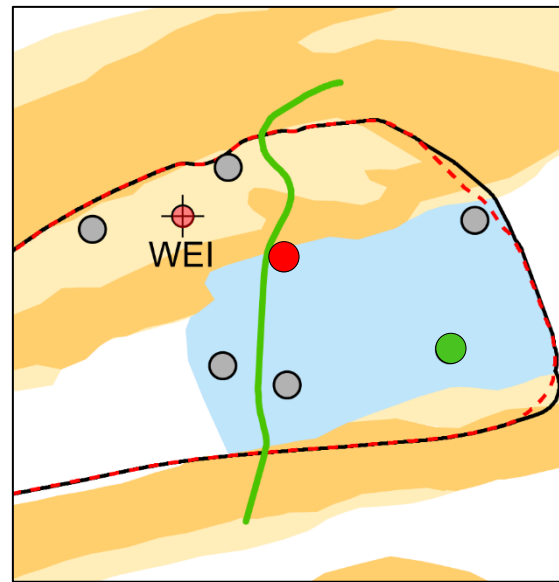
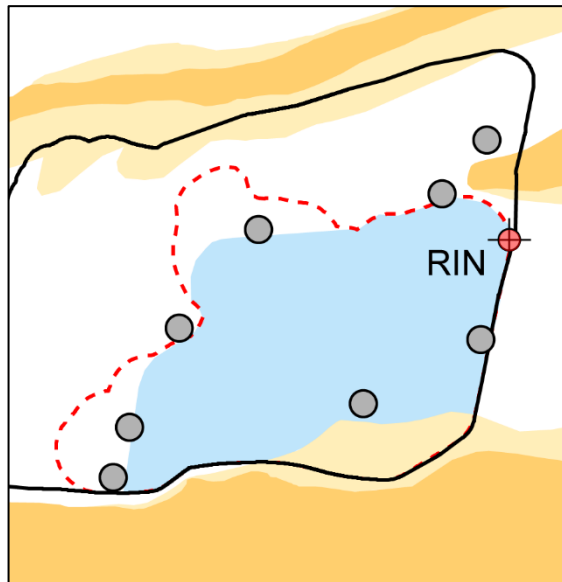
Drilling license application

- Justification of location (at the edge of most interesting regions)
- Catalog of methods: includes everything, excludes as little as possible
- → flexibility



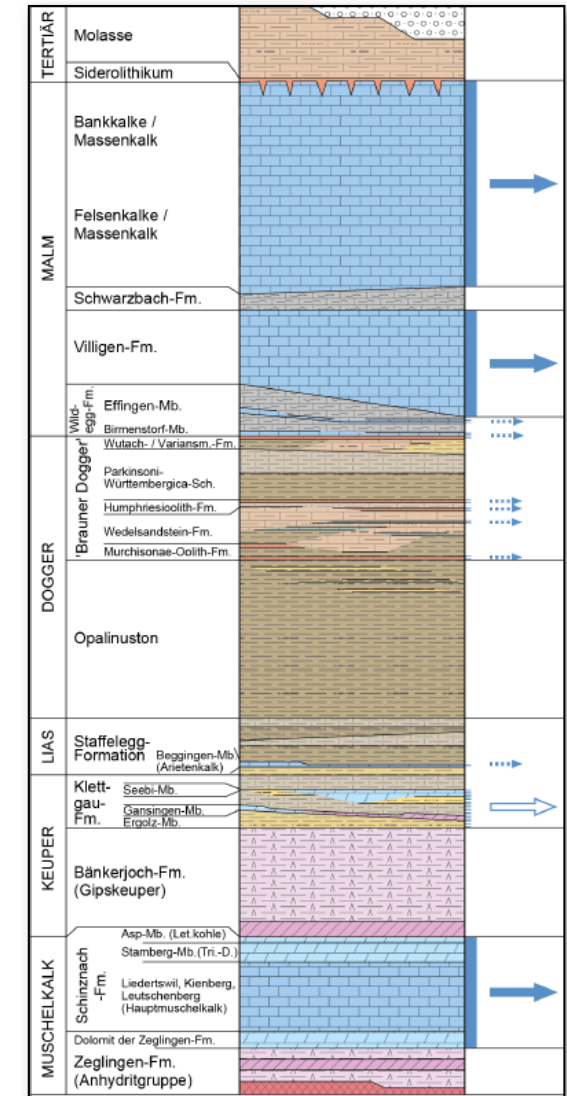
Drilling applications for deep boreholes

Until Sept. 2018	Jura Ost (JO)	Nördlich Lägern (NL)	Zürich Nordost (ZNO)
No. of sites handed in	8	6 (+1 until Dec. 2018)	8
Permits given	0	1	2



Investigation objectives of TBO campaign

- Assessment of spatial extent
 - Confirmation of thickness/depth/lateral extent of containment zone
 - Evaluation / Characterization of structural inventory
- Hydraulic barrier effect
 - Confirmation of hydraulic separation («Stockwerkbau»)
 - Evaluation of barrier efficiency of Upper/Lower Confining Units
 - Confirmation of barrier efficiency of host rock (ss)
- Long-term stability
 - Characterization of tectonic regime
 - Confirmation of THM Properties of host rock
 - Evaluation of conflict of use (permocarboniferous trough)
- Reliability of geological predictions
 - Evaluation of structural inventory
 - Characterization of continuity of Upper/Lower Confining Units
 - Confirmation of continuity of host rock (facial variability)
- Engineering suitability
 - Characterization of geotechnical properties of host rock and stress



Exploration boreholes – organisation, planning, tendering

- Tendering of different work packages (not general contractor):
 - Drilling company
 - Logging services
 - Hydraulic Testing
 - On-site geological investigations (multiple work packages)
 -
- Drilling at 2 sites in parallel

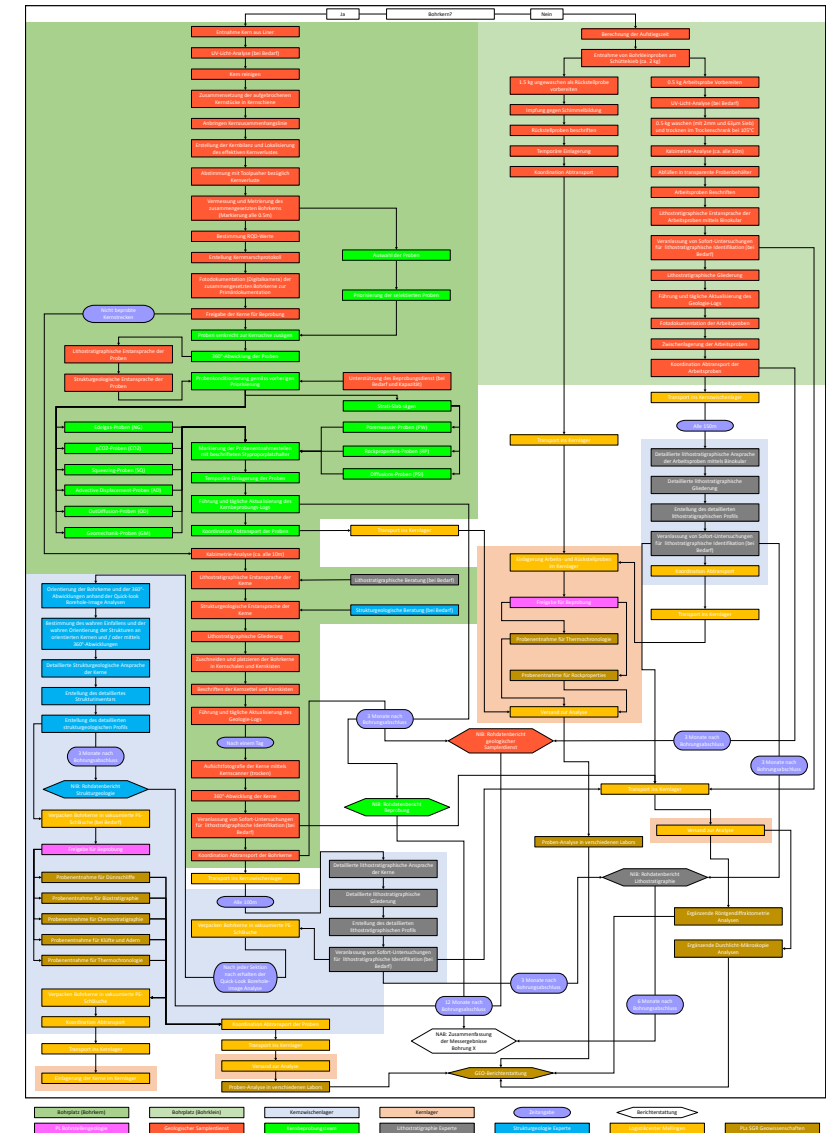


- Management of each work package remains by Nagra
- Detailed planning as basis for tender a requirement
- Optimisation of the interaction of the individual teams critical (time, resources)

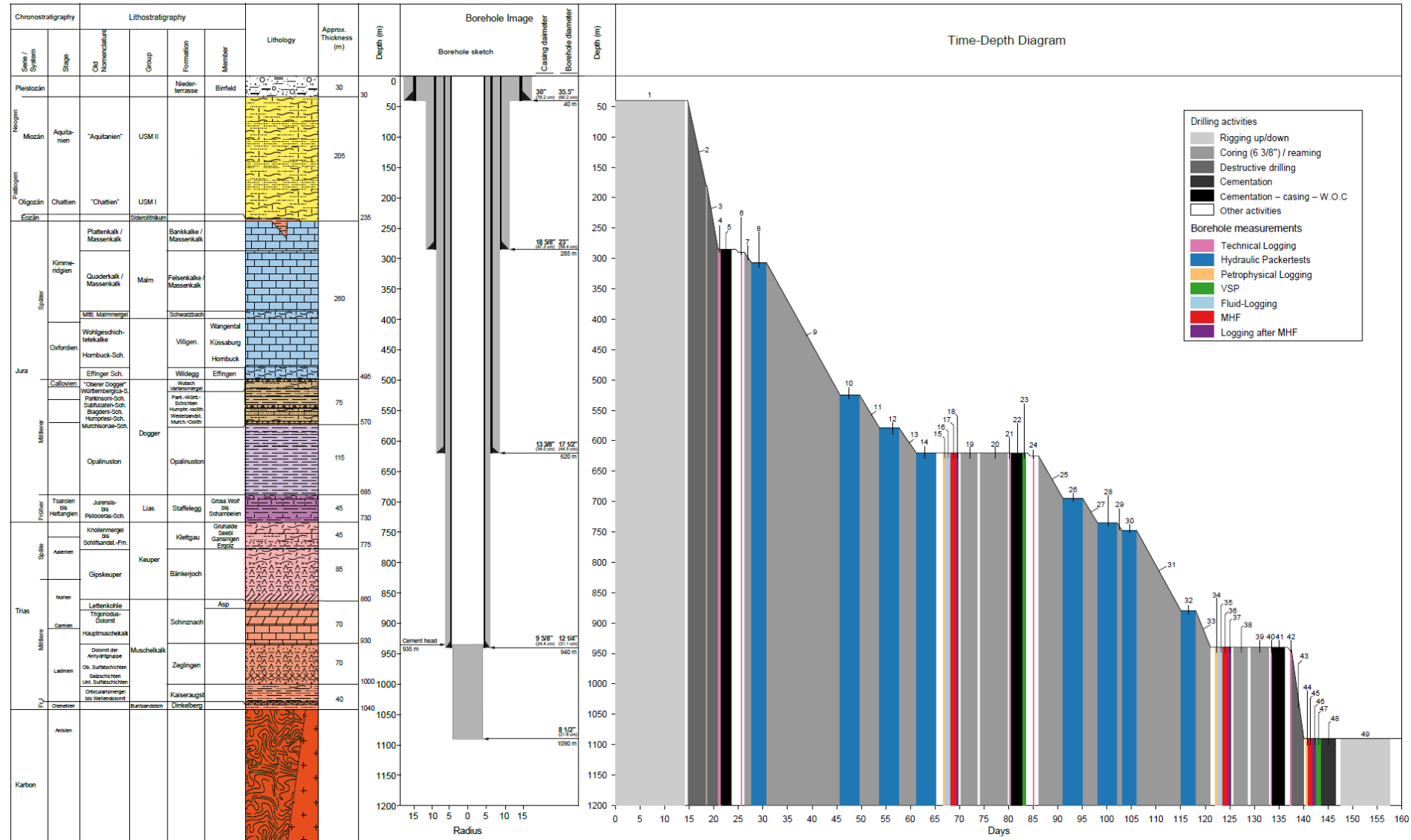
Borehole on-site geological investigations

Activities, flow diagram and interactions

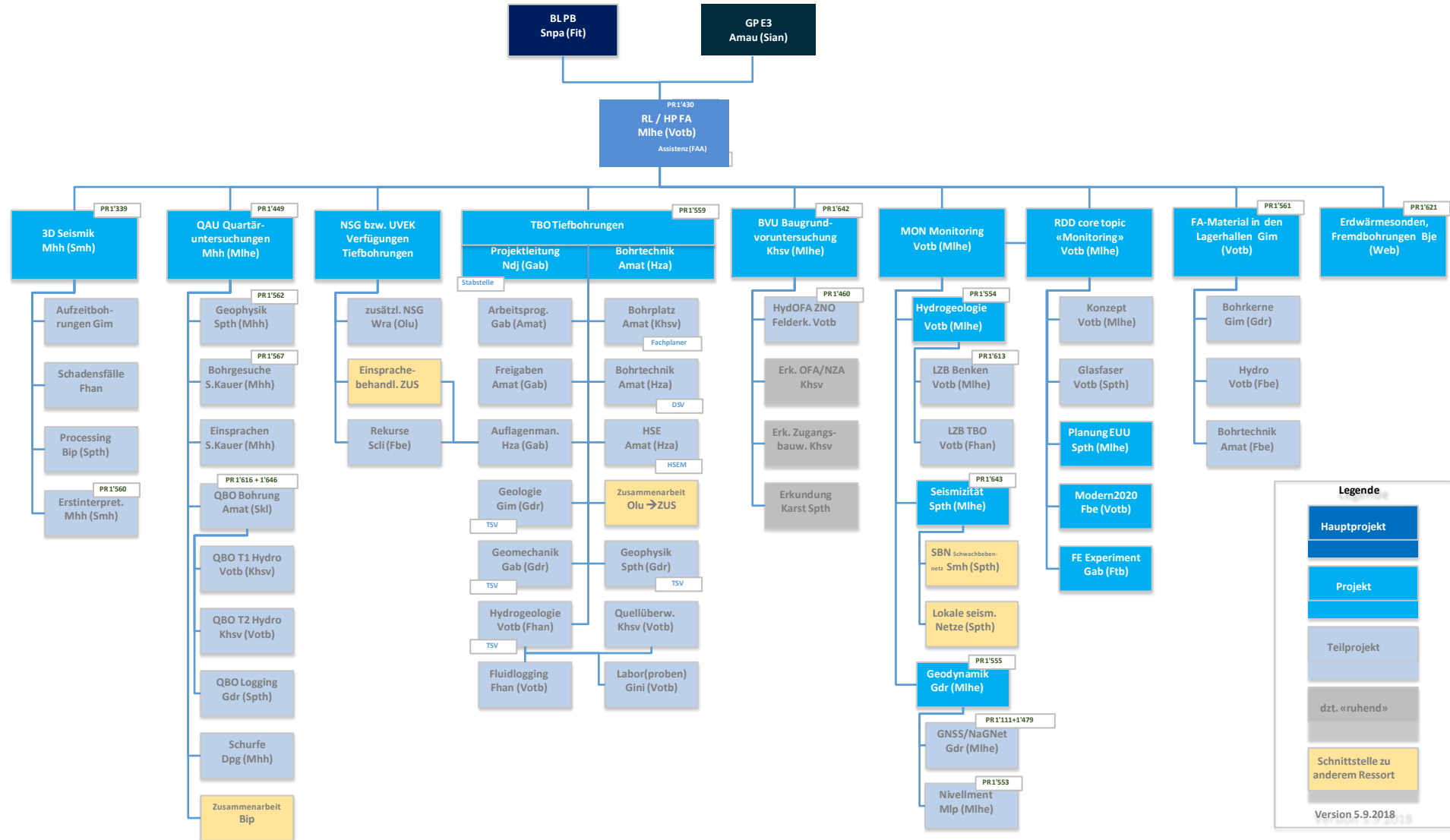
Background colors indicate the different teams involved



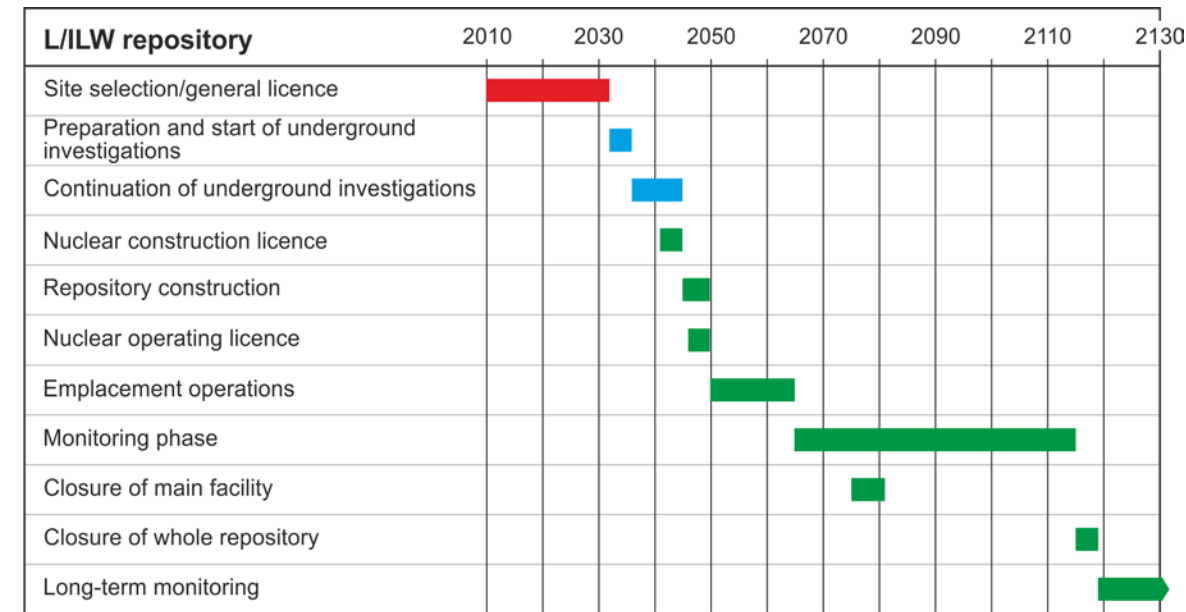
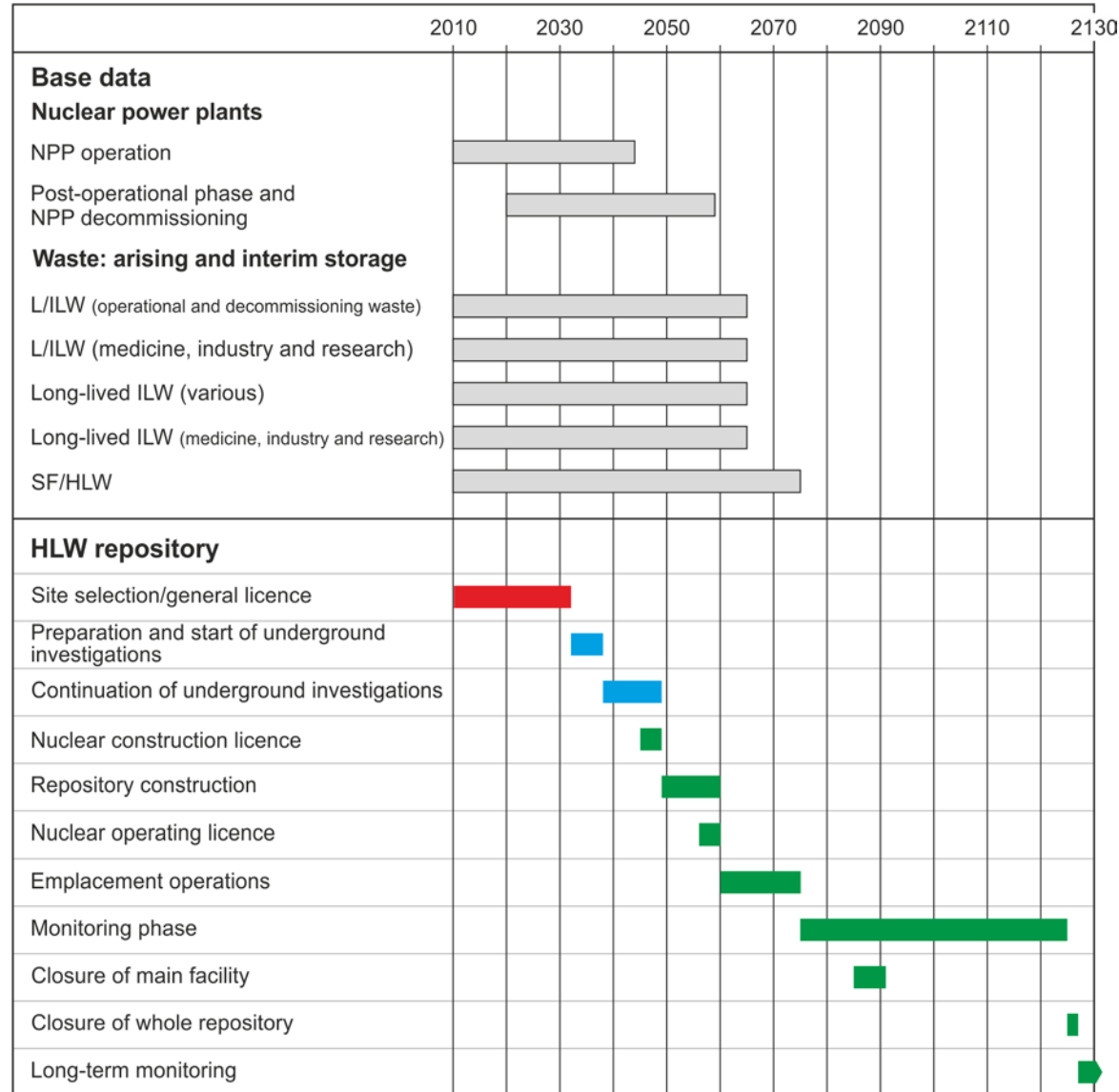
Time-depth diagram (for planning/costing)



Organisation of field activities and TBO



General schedule





thank you
for your attention
nagra.