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Urban Development of the Subsurface: Sketches from Switzerland

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Abstract: The space which cities need to develop is limited. People's demand for space to live and work in and generally enjoy is growing all the time (the amount of settled space in Switzerland increased twice as fast as the population between 1985 and 2009: at 23% compared with 11% (BFS: Die Bodennutzung in der Schweiz, Resultate der Arealstatistik [Ground Use in Switzerland, Results of Land Use Statistics]). In addition, immigration is on the rise, traffic requires ever more space, and pollution — particularly as a result of noise — is increasing exponentially, while the loss of land available for agriculture and the destruction of the landscape call for the spread of settled space to be curbed, for density and concentration, and for an emphasis on working inward and even downward when developing land for settlement. The city needs to use the space the subsurface offers for its development. The areas of the subsurface that might be used for construction are also associated with usable rock, geothermal energy, and drinking water.

Policy is little concerned with using the subsurface, urban planners are not familiar with it or its potential for urban development, the lack of geological expertise regarding the subsurface can result in damage (see section 4.4 below concerning StaufenimBreisgau), and spatial planning and related law pay scant attention to it as well. Any use made of it tends to be uncoordinated. This results in conflicts over use, and there is a growing danger the potential of the subsurface will not be fully exploited. The subsurface needs to be factored into spatial planning at all "levels" without exception, and particularly into planning in relation to urban development.

There is a lot of talk about three-dimensional urban development, but this is about applying the methods and instruments associated with (spatial) planning beyond the space at and above the surface and putting them to productive use for the underground dimension of space too. It is a case of ascertaining how far the law needs to concern itself with urban planning in relation to the subsurface, how well the existing instruments associated with spatial planning address the specific issues of using the subsurface, and to what extent special regulations regarding the subsurface are required at the various levels of planning. Other questions include how the various demands for use might be coordinated, to what extent the need for an overview calls for a new methodology, how far the law concerning the limits of land ownership and delimiting responsibilities and interests as regards use of the subsurface remains adequate, and whether 3D surveying provides sufficient support. These and similar issues will be addressed in the rest of this document, with special reference to the situation in Switzerland.

Key words: spatial planning, subsurface use, 3D cadastre, conflicts over use

1. Introduction

Demands to use the subsurface are growing all the time. The competition is diverse. In one and the same area, one party wants to use geothermal heat, another wants to lay a gas pipe, and a third hopes to build a tunnel, while all the various landowners would like heat from the groundwater too. Until now, use of resources in the subsurface has been uncoordinated, leading to conflicts over use and a danger the potential below ground may not be appropriately exploited. It cannot be right, however, to adopt a "first come, first served" attitude. Rather, all activities must be coordinated, as we are used to doing at the surface. The spatial planning phase — which is now indispensable — comes with a caveat in planning terms (no activities that impact on space without planning), and this in turn places a planning obligation on the authorities [1].

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The remainder of this document begins by highlighting the various types of subsurface use and the responsibility for regulating such use (section 2). This is followed by a discussion of a number of legal aspects (e.g., land ownership rights, authorizations/permits, regulations on use) (section 3). The last part outlines how planning works in relation to subsurface use (section 4).

2. Types of Subsurface Use and Responsibilities for Regulating Such Use

According to Swiss federal law, the cantons — i.e., the member states of the Swiss Confederation — are responsible for legislation in all matters not assigned, under the Federal Constitution, to the Confederation for it to legislate on. As such, there are no areas where neither of the two levels of government is responsible for legislation. Where the intention is to pass responsibilities to the Confederation, the Federal Constitution needs to be amended for each individual matter.

In Switzerland, the main distinctions are made between the following types of subsurface use [2-4].

2.1 The Subsurface as Somewhere to Build

The subsurface helps to anchor both buildings erected above ground (their foundations provide support and secure everything in place and also provide a shell for settlement activities) and structures created below ground (bridges, road tunnels, underground railroads, etc.), as well as serving as somewhere to run all kinds of pipelines. Stories below ground level have the advantage of being isolated from climatic influences and noise and being out of sight, although they do miss out on natural light, which makes them unsuitable as spaces where people need to spend long periods of time (somewhere to live or work). Having said this, there are also numerous buildings at the surface where there is often no natural light (particularly in shopping malls). The employees concerned are given so-called light breaks so they can "top up" on daylight and enjoy unrestricted views for a certain time (currently 20 minutes every half day) in the interest of their health (art. 15 of the guide to Ordinance 3 relating to the Swiss Employment Act of November 2016). In principle, any uses which are not permanently reliant on daylight can be moved to the subsurface, leaving the space above ground free for other uses — such as accommodation, offices, relaxation areas, and urban spaces.

As a rule, stories below ground are not subject to provisions regarding minimum distances between things or limits imposed on the height or depth of structures, as is the case for buildings above ground. This basically means there are no limits to the horizontal and vertical dimensions of stories below ground, although in terms of public law, this may be opposed by legal regulations regarding either the protection of trees or groundwater. Groundwater protection in particular needs to be considered from many different aspects. For example, it governs the extension of underground structures in both a horizontal and vertical direction, thereby limiting the number of stories below ground, and imposes criteria for the arrangement of culverts (i.e., the pressurized pipes which help groundwater overcome obstacles).

Further limits to ground used for construction also need to be considered. For one thing, the subsurface just below street level contains utility and communication networks. So it is a case of considering the urban context and the characteristics of the specific location where underground structures are to be built, as well as the acceptability of uses of the space below ground in urban areas. These are also connected to the geological and hydrogeological conditions at the site. Much importance here is attached to the techniques applied in the construction of underground works. And ultimately, cost is another criterion when deciding whether to build below ground.

In the subsurface, where daylight may not necessarily be needed? The Balestra multi-story car park in Lugano, with its eight stories for parking and its

overall volume, takes up a very large amount of space above ground that could be better used for residential and work purposes. On the other hand, the geological and hydrogeological conditions may mean there is not enough space to accommodate this kind of volume in the subsurface. And it is ultimately no small thing that a structure which succeeds in architectural terms can really add to the urban landscape, even if it is "only" a humble car park.

Motorized traffic is claiming an ever increasing amount of space below ground, which can also help relieve some of the pressure on the city above ground and the space above ground in general. Much of the traffic skirting around or passing through cities is diverted through tunnels. In some cases, it is deemed appropriate to divert goods traffic in particular, and the bulky carriers used, through the subsurface. The recently launched *Cargo sous-terrain* (Underground Cargo) project intends to relieve the pressure on roads and railway routes by using an underground tube with permanently self-driving vehicles to transport goods.

Goods traffic is to be diverted below ground, with unmanned carriages transporting standardized pallets along three-lane tunnels 24 hours a day. The tunnels containing the tubes will run at a depth of 20 to 50 m and be around 6 m in diameter. The tubes will contain three lanes: one for either direction, and a service lane in the middle. The vehicles are to be propelled and steered by electromagnetic induction. Power is conducted down lines in the floor of the tunnels.

Fig. 1 Balestra multi-story car park in Lugano (photograph: A. Ruch).

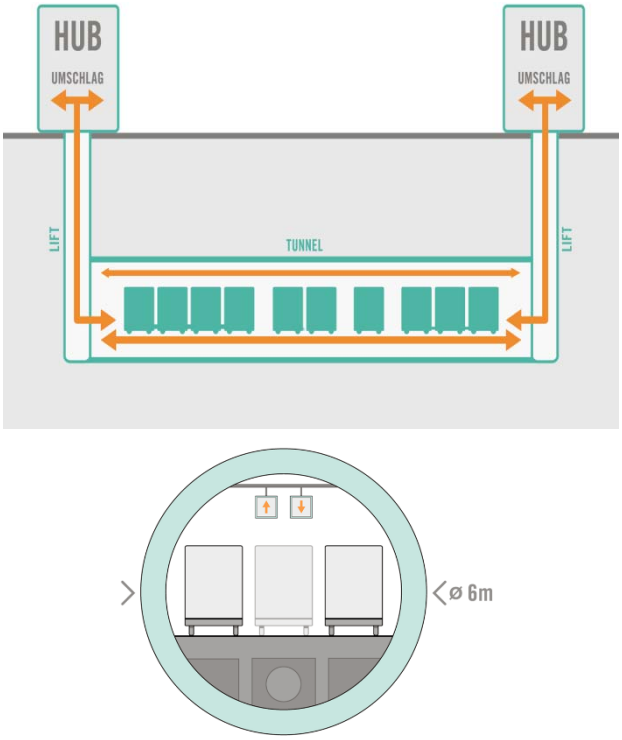

Fig. 2 Underground Cargo, longitudinal and cross section.

Regulation of subsurface use for construction purposes is a matter of construction law and therefore a job for the cantons. The Confederation does, however, have some sectoral authority in terms of construction law, particularly in relation to classic infrastructure elements such as railroads, freeways, airports, energy supply facilities, and telecommunications, where the Confederation grants the relevant permits. Then there are a number of federal laws that contain provisions relating to construction law that must be applied when making any decisions in the area of construction law. These include environmental law and the law regarding groundwater protection in particular.

2.2 Subsurface Use for Disposal Purposes

Subsurface use for disposal purposes is less of an issue these days in urban areas. It is only referred to here for the sake of completeness.

Regulation of subsurface use for disposal purposes is the responsibility of either the Confederation or the cantons, depending on the matter involved. For example, the Confederation is responsible for waste

facilities and the storage of radioactive waste, while legislation on CO_2 storage is a matter for the cantons. It would be fair to say the Confederation is responsible for the framework legislation on environmental and groundwater protection and that uniform provisions apply across Switzerland in these areas.

2.3 Procurement of Raw Materials

Unlike the two types of subsurface use described above, the procurement of raw materials highlights the natural properties of the subsurface. It is not a case here of developing space for human activities, but of exploiting the internal elements of the subsurface. Raw materials are simply there — without humans having to do anything. This particular piece is concerned with those raw materials (geomaterials: rock and earth) which are needed in cities (these are also mined in urban areas in some cases). These are mineral materials used as granular matter in the manufacture of concrete and asphalt, materials for the manufacture of gypsum and cement, natural rock for buildings above ground, and debris for road building. Ever more geomaterials are being used for construction purposes, which need to be transported from ever further away. High-quality hard rock can be found in a narrow band between Lake Constance and Lake Geneva and often lies in protected landscapes [5]. As such, there is a growing need to tap into new gravel stocks and open up new quarries, which points to conflicts with other uses and competing demands for use [6].

Regulation of the procurement of geomaterials, particularly quarries and gravel pits, falls within the authority of the cantons [7]. The Confederation has no authority to issue any binding provisions.

2.4 Storage and Use of Groundwater

Groundwater is also a raw material, but its special significance and the diverse ways it can be used deserve to be described separately. There is sufficient groundwater of good quality almost everywhere in Switzerland. In urban areas, however, it may also contain undesirable foreign matter (e.g., VOCs, particularly tri- and tetrachloroethylenes/solvents, PFCs from the drains in settled areas, gasoline additives used as antiknock agents, medicines) (for more information regarding such problems, see the publication by BAFU titled Ergebnisse der Grundwasserbeobachtung Schweiz NAQUA; Zustand und Entwicklung [Results of Groundwater Monitoring for Switzerland NAQUA; Status and Development] 2004-2006, 3/09, p. 62). And urban areas tend to leave something to be desired in terms of groundwater protection [8]. The ground, whose layers protect water, plays an important role in the quality of groundwater.

Over 80% of Switzerland's drinking water is obtained from groundwater. Groundwater is also used for extinguishing and industrial purposes in urban areas. And it is increasingly being used as a source of energy. Groundwater is used to generate heat too, but unlike geothermal energy, heat is drawn directly from the groundwater itself propelled by groundwater heat pumps (direct thermal use).

Regulation of groundwater is solely a matter for the Confederation. It has had the authority to issue legislation on groundwater protection since the start of the twentieth century, and the relevant act with its detailed ordinances (secondary legislation by the national executive) is already the third comprehensive act passed in relation to groundwater protection. Drinking water is considered to be a foodstuff, an area where the Confederation also has sole responsibility for legislation. The Confederation has issued framework provisions for the protection of groundwater in planning terms, while implementation of plans is a job for the cantons.

2.5 Subsurface Use for Obtaining Geothermal Energy

Use is made of the geothermal heat stored in the subsurface. Heat increases with depth, with a distinction (still) generally made between shallow and deep geothermal energy. This distinction relates to what is possible in technical terms. For the purposes of

the matters discussed here, this distinction will be ignored [9]. Shallow geothermal energy covers depths down to 400-500 m. Heat is drawn from groundwater using geothermal heat probes, ground heat exchangers, geothermal baskets, energy piles, and similar thermoactive elements (for information on indirect thermal usage, see the publication by BAFU entitled Wärmenutzung aus Boden und Untergrund; Vollzugshilfe für Behörden und Fachleute im Bereich Erdwärmenutzung [Using Heat from the Ground and Subsurface; Implementation Guide for Authorities and Specialists in the Field of Geothermal Heat Use] 10/09, p. 18; and by CHGEOL entitled Die Nutzung des geologischen Untergrunds in der Schweiz; Empfehlungen des Schweizer Geologenverbands zur Harmonisierung von Verfügungshoheit, Sachherrschaft und Nutzungsvorschriften [Use of the Geological Subsurface in Switzerland; Recommendations from the Swiss Association of Geologists on the Harmonization of Rights of Disposal, Physical Control, and Provisions Relating to Use]). Shallow geothermal energy is of significant importance in cities, particularly for single-family dwellings and smaller buildings in peri-urban areas.

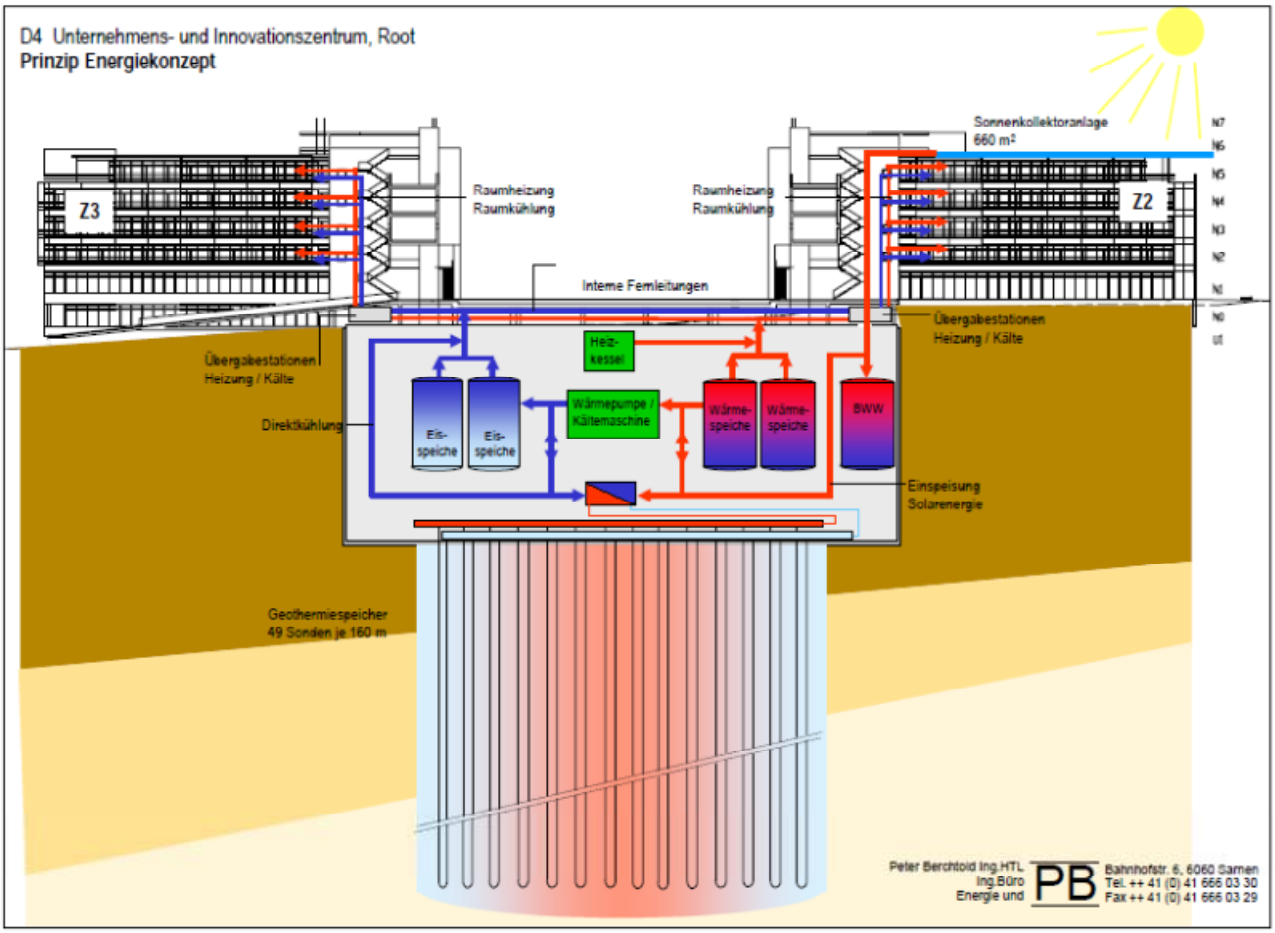

Fig. 3 Energy strategy, soil as a store of solar heat? (Florian Rusch, *3rd Swiss Conference on Solar Heat,* November 12, 2014).

Geothermal energy from greater depths is also suitable for providing buildings with heat. It has an important role to play in intelligent approaches to urban energy supply. Following initial drilling in 1988, geothermal heat from an aquifer at a depth of around 1,500 m has been used at Riehen near Basel for 20 years. In densely settled areas, groups of buildings are supplied from surrounding thermal fields, each of which is connected to a network (GeoDH report: European Geothermal Energy Council, Developing

geothermal district heating in Europe, 2014, February 23, 2015, p. 12).

The possibility of conflicts with other subsurface uses is very high and increasing. Deep geothermal energy, which can be used to generate heat and power, is somewhat different. Although it does also have a role to play for urban areas (apart from Basel, see also the revived project in Zurich's Triemli district), the installations concerned are less significant in numerical terms.

Regulation of geothermal energy is a matter for the cantons. It is worth noting in turn that specific federal laws also have to be applied to decisions relating to geothermal energy projects, particularly in terms of the law regarding groundwater and environmental protection.

3. The Law Governing Subsurface Use

3.1 Land Ownership Rights and Rights of Use

Two categories of parties with rights of disposal are competing for the subsurface: the landowners, whose right of disposal also extends downward, and the "public authorities", who have right of disposal over those areas that do not count as landed property. For the purpose of delimiting things, it is a case of ascertaining how far (private) landed property extends and the depth below which the canton enjoys sovereignty in terms of use. If there are plans to route a railroad tunnel under a built-up area, the construction company will want to know whether the tunnel will need to make use of private landed property and whether disputes with landowners will arise, while the landowner will want to know whether it can now build its geothermal heat probe without further ado or will have to wait for the disputes mentioned to play out.

The limits of a plot are defined horizontally by markings and the entries made in the land registry plans on the basis of official surveys. The relevant limit applies until it is amended by virtue of some formal procedure. Things are rather different as regards the vertical. Landed property extends as far down (and up) as the landowner has an interest to exercise; i.e., it does not extend to center of the earth as is the case in other countries. This is governed by art. 667 para. 1 of the ZGB (which means private law at federal level determines how far landed property extends). Anything beyond these areas of interest or control falls within the (legislative) sovereignty of the cantons. The peculiar thing about landed property and depth is that any limits are not plot-specific but essentially remain open, with the extent of land ownership varying with the intentions of the respective landowner, so are therefore dynamic and cannot be delimited on a permanent basis [10, 11]. The relevant specific interest of the landowner may extend no further than the basement, although it may extend to four underground parking stories or incorporate heat probes of different horizontal and vertical reach.

The idea of an interest to exercise [3, 11] has both a positive and a negative side. On the positive side, it must be actually possible for the landowner to exercise the specific use in question; it must have control over the space and be able to exercise the authorizations for use associated with the landed property "without any particular difficulties or excessive effort" (BGE 93 II 170, 1967, p. 176 E. 5). On the negative side, third parties may only exercise rights of use insofar as these do not undermine the positives aspects of the landed property. This concept of landed property definition has a demarcation role (BGE 119 Ia 390, 1993, p. 398 E. 5c/bb). For example, art. 664 para. 1 of the ZGB stipulates that ownerless and public objects — to which the subsurface is also allocated — come under the sovereignty of the state in whose territory they are located. The "state" in this context refers to the cantons. This means the cantons can assert their right of disposal on the subsurface, providing landed property, as defined under civil law, is not affected as a result. Beyond the "sphere of interest" of landowners, there is no private landed property. Priority is given to the public realm (primacy of the public sphere; BGE 119 Ia 390, 1993, p. 399 E. 5d). "Sovereignty" also means the

cantons can stipulate the type of use. They enjoy a monopoly position in relation to the pursuit of economic activities involving the subsurface as just outlined (see also the end of section 3.3).

3.2 Peculiar Aspects of the Legal Concept of the Subsurface

There is no legal definition of the subsurface in federal law. A look through the cantons' collections of laws reveals, for example, that the applicable law in the canton of Aargau, from June 19, 2012, regarding use of the deep subsurface and procurement of natural resources in the ground rules as follows: "Use of the deep subsurface is understood to mean underground uses that do not involve landed property protected under private law" (section 2 para. 2). The model law for the cantons of northeastern Switzerland, from December 2, 2013, regarding use of the subsurface sets out the following: "The subsurface is deemed to be that part of the earth's interior which is not covered by civil law at federal level" (section 2 para. 1). In decrees issued under public law at canton level, such as the two referred to, there is clearly a trend toward understanding the subsurface to be only what lies below the earth's surface, beyond landed property protected under private law, and can be governed by public law [12]. There is no uniform legal definition of "subsurface".

In construction law, "underground" does not simply mean "covered with earth"; what matters is the ground under which the underground structure is situated. In general, the decisive factor here is natural ground (verdict B 2011/77 by the Administrative Court of the canton of St. Gallen from March 20, 2012, E. 4.2, with reference to individual communal laws whereby the decisive factor is ground that has been shaped and filled).

3.3 Authorizations: Types and Responsibilities

Two types of authorizations apply here: construction permits and licenses. All structures and facilities may only be created or modified across Switzerland with official permission in accordance with the relevant provision of federal law. It makes no difference whether the builder involved is a private individual or a community. Official permission is required not only for actual building work in the subsurface, but also cables, facilities for generating heat, pits, drilling work (including test drilling), and seismology surveys. No distinction is made between permanent or temporary installations. Permission is broadly referred to as a construction permit. And this is also what is meant where cantonal laws give different names to specific types, such as when permission for a geothermal heat probe/heat pump facility or permission for facilities in areas with usable groundwater stocks are referred to as a water protection permit (because water protection law is at the heart of the matters under consideration) [13]. The construction permit does not give the owner any new rights, but only allows him to build and operate the structures.

The use of raw materials and the like requires a so-called license, up front, in addition to the construction permit for the facilities. It represents a conferring of rights, i.e., it gives the recipient the right of use. This is protected by the guarantee of the right of ownership, so can only be withdrawn or diminished by means of expropriation. The holders of any right granted are the cantons (see the last sentence of section 3.1 above), and they are able to exercise it themselves or grant it to third parties.

3.4 The Subsurface As Somewhere to Build

Various sets of laws apply here. Priority is given to spatial planning and construction law at canton and commune level, which is basically applicable to all structures with an actual settlement function, such as the underground parts of residential, commercial, industrial, or public buildings. This also includes utility facilities such as water pipes, electricity cables, and wastewater pipes, as well as individual structures like car parks. There are no specific statutory regulations

regarding underground structures and facilities. Any general legal, professional, and other standards apply to them too (as regards air, see [13]).

Construction laws talk about building over plots, about the height of buildings, and their depth (which serves as a measure for a certain length of facade). Stories below ground do not count toward any maximum dimensions for usage purposes, which means underground structures and those parts of buildings located underground can free up more space for use. Underground parts of buildings must not extend beyond the confines of the parcel of land concerned for reasons associated with landed property law. But the depth of underground parts of buildings is unlimited in principle in terms of construction law as applicable to communes. As already outlined (see section 2.1 above), water protection law at federal level contains restrictions regarding depth in the interest of groundwater protection.

3.5 Procurement of Raw Materials

The procurement of raw materials comes under the so-called mining prerogative right. Prerogative rights are cantonal monopolies which predate the issue of the Federal Constitution in 1874. They allow the cantons to apply exceptions to the principle of economic freedom which would otherwise not be available to them in support of their activities (only the Confederation can conduct economic policy). Prerogative rights have their legal basis in the cantons' constitutions and may be enacted in a special law (Mining Prerogative Act, "Subsurface Act", and the like). The prerogatives involved mainly apply to the ground, such as mining and salt prerogatives. The monopoly gives the canton the exclusive right of use, which it can pass on to other parties, e.g., private individuals, by conferring rights (a license) (see section 3.3 above).

4. Coordinated Planning of Subsurface Use

4.1 Planning System

The system of spatial planning in Switzerland covers several instruments which make up a kind of hierarchy. There is a higher strategic and coordinating level in the form of the *structural plan*, which the cantons are responsible for issuing. With measures to reconcile matters across the cantons, this is intended to create a whole applicable to Switzerland in its entirety. Structural plans are binding on the authorities, particularly those who then define *land use plans*. This second level may be described as the regulatory level [8]. Land use plans are binding on all parties and determine possible uses in detail down to individual plots of land. The communes are generally responsible for issuing these and have to get the cantons to approve their land use plans. The third level covers (construction) *permits* issued for individual projects, as well as stipulations regarding land use planning and any applicable legal provisions that need to be complied with.

The subsurface is to be understood as an integral whole in which the various uses interact [8]. Just as in principle each structure or installation constitutes a system which not only comprises the object (building, road, pipe) but also has an impact on the environment (noise, vibrations, air pollution), each project needs to be understood in a broader sense. Within the subsurface, it is especially important to record objects and their mutual influences, because there are fewer restrictions on heights and it is much harder to get an overview of conditions compared with at the surface. Therefore it is important to prepare the required informations about the subsurface within the planning process (see the cautionary tale section 4.4 para. 1 below as well).

The following diagram represents the various types of use within the subsurface and they how influence and interfere with each other.

The need for comprehensive coordination is all too clear from the diagram. This demands that the relevant data and information concerning the subsurface be systematically recorded, that the possible uses the subsurface offers be determined, and that any future

uses be planned. The uncertainties which exist during these phases make a particularly compelling case for forward-looking spatial planning, which — thanks to its capacity to manage crossover issues — can deliver a supra-local and supra-disciplinary brand of holistic spatial planning based on the relevant risk conditions [14]. As such, spatial planning precedes any individual decisions and generates information (about, say, geology) that provides the basis for spatial planning. This applies to both models: both the one focusing on needs and the one focusing on the potential of the subsurface [15]. Coordination is the core task in terms of spatial planning and the one with the highest priority. This applies to conventional spatial planning, due to the specific local conditions, but particularly to spatial planning involving the subsurface.

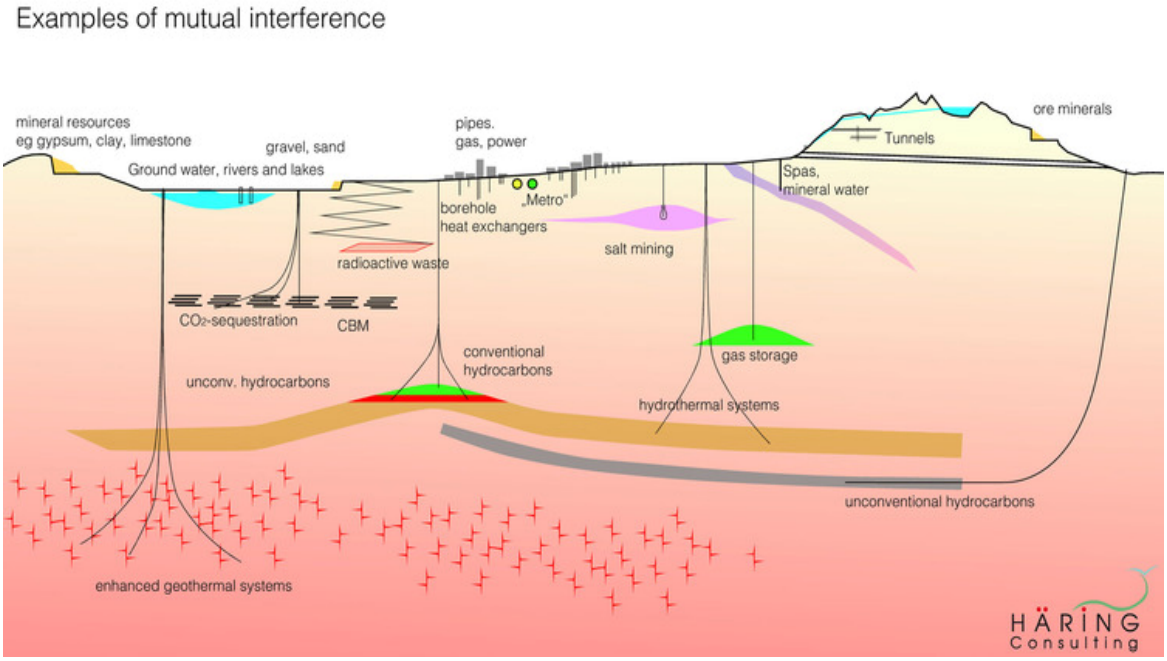

Fig. 4 Examples of mutual subsoil interference (Markus Häring, Häring Consulting, 2015).

4.2 Structural Planning

The instrument to be used across Switzerland for coordinated planning (reconciling the various activities with an impact on space, both existing ones and any still at the planning stage), which contains stipulations that are binding on the authorities, is the cantonal structural plan or structural planning. Structural planning is the ongoing process, while the structural plan is the relevant snapshot when plans are actually defined. “Binding on the authorities” means the authorities issuing the planning for the next level that is binding on everyone — land use planning (see section 4.1) — are bound by what is set out in the structural plan. All projects with a significant impact on space and the environment must have some kind of basis in the structural plan (art. 8 para. 2 of the RPG); this essentially means any projects that need to be coordinated with other projects. The structural plan consists of a map and text, both of which are equally binding. The map depicts the locations of activities, while the text details what has been set out in word form, rather than simply providing an explanation of the map.

There is no cantonal structural plan specifically concerned with the subsurface. Registration of groundwater stocks, as well as cantonal areas of interest for groundwater use, involves a coordinated approach. The structural plan may envisage some prioritization, besides showing the need for reconciliation [7]. The existing cantonal structural plans still say nothing about, say, drilling for

geothermal energy, even in those cantons which have already forged ahead with such work. The structural plan makes occasional reference to overviews showing areas in which, for example, geothermal heat probes are permitted (see the structural plan for the canton of Thurgau, section 4.2, p. 9, which is not yet, of course, a planning-related service). But the normative criteria in the structural plan may also apply, to all intents and purposes, to the planning of subsurface uses. It will be necessary, however, to contemplate three-dimensionality in terms of how things are represented. The peculiar thing about (structural) planning in relation to the subsurface is how reference to underground uses is made at the surface [9]. Because there is no such thing as purely underground planning, with all activities having some impact on the surface [7]. From a planning perspective, the talk would be more about the overall "underground dimension" of the city — as opposed to the "underground city".

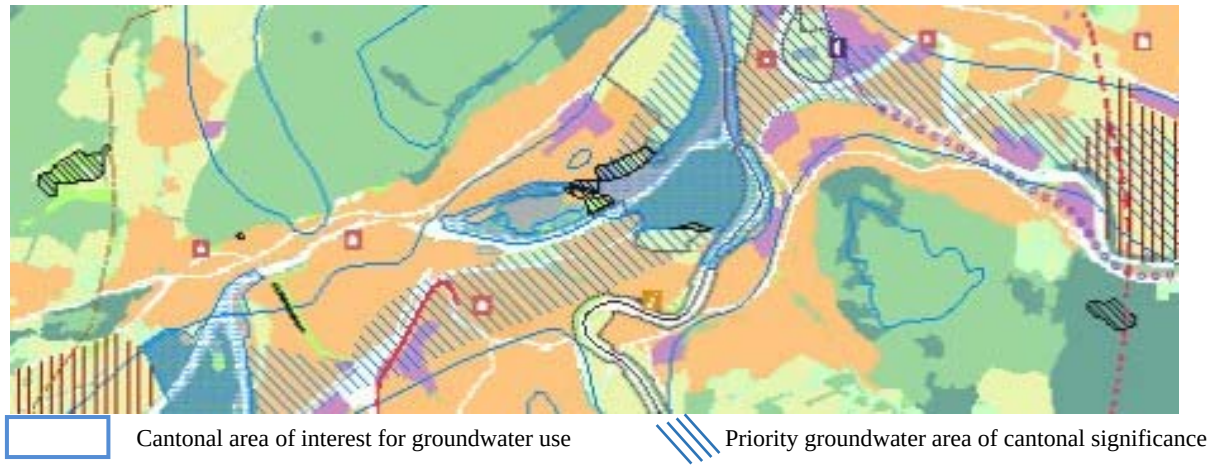

Fig. 5 Structural plan for the canton of Aargau (detail: Brugg – Windisch – Turgi).

4.3 Land Use Planning

Land use planning is the next level in the planning hierarchy. The specific possible uses are defined, in terms of sovereignty, in a land use plan — these days usually at commune level and by the legislator for the commune. The land use plan is binding on all parties, particularly the landowners and any other parties with rights and obligations in respect of the land and ground. Things are set out in terms of property (down to "individual plots" of land) within zones. There are land uses (e.g., three-floor residential zone, commercial zone associated with moderate disruption, industrial zone) and so-called overlying zones (e.g., water and groundwater protection zones, preservation orders, natural hazards). Whereas the structural plan only contains projects that require some coordination, the land use plan has to contain anything that needs to be defined regarding local arrangements for approved use of the ground. The land use plan is also drawn in two dimensions but needs to be understood in three; it restricts itself, however, to ground use and mainly how this takes effect above ground [7]. It would also have to be possible to issue the underground land use plan as a three-dimensional representation. As regards subsurface use, the land use plan, which would be used first and foremost for planning in relation to the shallow subsurface, would be able to give landowners some certainty [9].

4.4 Three-dimensional Modeling and Creation of Cadastres

In the old town of Staufen/Breisgau (Germany), the sinking of a number of geothermal heat probes in 2006 led to water ingress in dry sections of swelling rock. This resulted in so-called Gipskeuper swelling, whereby anhydrite swells in the presence of water to become gypsum and increases in volume by up to 60%.

This prompted the old town to rise (it is still rising), which causes considerable damage to buildings with significant financial implications [16] (see also the example for [17]). Such damaging situations should be tackled by finding out about the condition and physical properties of the subsurface. The tool for this is the geological 3D model, which was first created in Basel as a project-specific model for addressing issues limited to the locality, particularly relating to groundwater and earthquake protection, but is now being developed into a 3D layer model that can be used to evaluate various possible uses. In the meantime, the goal is to develop a dynamic 3D model as a tool for underground spatial planning [18].

The geometric documentation of landed property by means of official surveys (3D landed property) is now a task of equal importance to both use above ground and use of the subsurface. Then there are the documentation and administration of the space above and below the ground. From a technical perspective, it is possible to document and administer 3D problems in a legally compliant manner. The aim is to create a legally binding 3D cadastre [19, 20]. The 3D cadastre should be feasible in the near future — at least in urban centers [9]. There is also talk of a market for underground landed property [21].

The use of plots of land is subject to many public-law restrictions on land ownership (öffentlichrechtliche Eigentumsbeschränkungen or ÖREB), which are binding on landowners. These are based on what is decreed by legislative authorities (laws, ordinances, plans) or decisions by administrative authorities (plans, orders). There is still no central source of information for ÖREB. The ÖREB cadastre will close this gap by collating information from various areas (e.g., land use plans, project zones, building lines, groundwater and flood protection zones, noise sensitivity levels, height limits, safety zones) that are not included in the land register governed by civil law. The legal framework for the ÖREB cadastre is to be defined by the Confederation, with the cantons

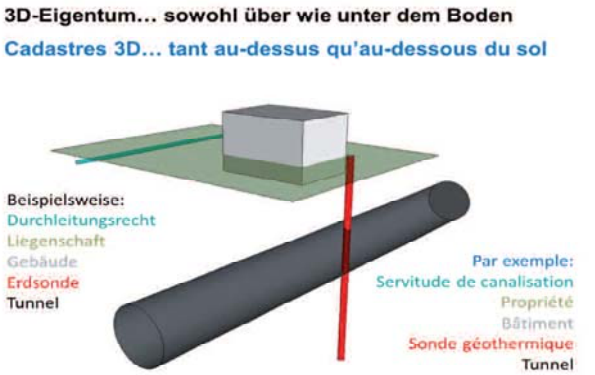

Fig. 6 3D-property, above- and underground (from: Åström Boss, 2014, p. 614).

organizing how the cadastre will be managed and determining the bodies responsible (Swiss Geoinformation Act of October 5, 2007, art. 16; see also the Ordinance on the Cadastre of Public-law Restrictions on Land ownership, ÖREBKV, of September 2, 2009).

5. Conclusion

Here are eight key points which could prove significant as regards planning for the underground dimension of the city [22, 23]:

- Taking account of the entire subsurface, regardless of depth (making no distinction between the shallow and deep subsurface);
- Taking account of all types of projects and uses, regardless of the scale;
- Comprehensive assessment of any impact on the environment;
- Creation of adequate legal foundations (in the RPG, in laws at canton level);
- Revitalizing spatial planning instruments, primarily in terms of structural planning and the structural plan, attempting to represent things in three dimensions. The land use plan should also be used to designate uses of the subsurface;
- Better “interlinking” of the approval processes to be developed on the basis of specific laws (e.g., laws on mining prerogatives and the Swiss Nuclear Energy Act, Railways Act, and Federal Act on Highways);

- Making coordination of projects a matter of "routine";
- Harmonization of provisions at both canton and commune level.

A group of experts concerned with "Use of the Subsurface" was set up in 2012. This was established as a private initiative and represents a loose grouping of natural persons with an interest in issues relating to use of the subsurface in Switzerland. Its mandate is to help improve coordination of how the subsurface is used by researching and developing concepts and strategies — particularly from a methodological, organizational, planning, legal, technical, political, and social perspective. The (voluntary) work involved is performed to academic standards. The group of experts is led by a three-person steering committee. The group runs two workshops a year and is involved in interdisciplinary projects. It also does work for government bodies and is currently, for example, involved in legislative projects at federal level.

Abbreviations

ARE Bundesamt für Raumentwicklung (Federal Office for Spatial Development)
BAFU Bundesamt für Umwelt (Federal Office for the Environment – FOEN)
BFS Bundesamt für Statistik (Federal Statistical Office)
BGE Entscheidung des Schweizerischen Bundesgerichts (Decision of the Swiss Federal Supreme Court)
BR Bundesrat (Federal Council – Government of Switzerland)
CHGEOL Schweizerischer Geologenverband (Swiss Association of Geologists)
E. Erwägung (deliberation – in the context of court rulings)
EGK Eidgenössische Geologische Fachkommission (Federal Geological Commission – FGC)
GEODH Geothermal district heating
IDHEAP Institut de hautes etudes en administration publique (Swiss Graduate School of Public Administration)
PFC Perfluorinated chemicals
PNR Programme national de recherche (National research program)
RPG Bundesgesetz über die Raumplanung (Federal Act of June 22, 1979, on Spatial Planning – with significant changes made on June 15, 2012)
SSV/IGGK Schweizerischer Städteverband/ Interessengemeinschaft Grosse Kernstädte (Swiss Cities Association/Interest Group for Major Core Cities)
URP/DEP Umweltrecht in der Praxis/Droit de l'environnement dans la pratique (Environmental Law in Practice – journal)
VOC Volatile organic compounds
ZBGR Schweizerische Zeitschrift für Beurkundungs- und Grundbuchrecht (Swiss Journal of Notarization and Land Registry Law – journal)
ZGB Schweizerisches Zivilgesetzbuch (Swiss Civil Code of December 10, 1907)

Legend to Illustrations

Underground Cargo:	
Umschlag	Transfer
Soil as a Store of Solar Heat?:	
D4 Unternehmens- und Innovationszentrum, Root	D4 Corporate and Innovation Center, Root (town)
PrinzipEnergiekonzept	Principle of energy concept
ÜbergabestationenHeizung/Kälte	Transmission station, heat/cold
Direktkühlung	Direct cooling
Geothermiespeicher	Geothermal energy store
49 Sonden je 160 m	49 probes every 160 m
Raumheizung	Heating for space
Raumkühlung	Cooling for space
Interne Fernleitungen	Internal pipelines
Eisspeiche	Ice store
Heizkessel	Boiler
Wärmepumpe/Kältemaschine	Heat pump/Refrigerator
Wärmespeiche	Heat store
BWW	Hot service water
Sonnenkollektoranlage 660 m^2	Solar collector system 660 m^2
EinpeisungSolarenergie	Solar energy infeed
3D landed property:	
3D-Eigentum… sowohl über wie unter dem Boden	3D landed property… both above and below ground
Beispielsweise:	For example:
Durchleitungsrecht	Transmission right
Liegenschaft	Property
Gebäude	Building
Erdsonde	Geothermal probe
Tunnel	Tunnel

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