EXTENDED ABSTRACT

Relocating a city, challenges and opportunities for the transition of water infrastructure in Kiruna

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INTRODUCTION

The city of Kiruna in Northern Sweden has become known for the need to relocate major parts of the city. Current and future mining activities in the world's largest underground iron ore mine are the cause of land subsidence that requires relocation of substantial parts of the town including its water infrastructure. Figure 1 shows the area currently affected and projections thereof for the future. The process of relocating the city has started already and will continue for a few decades. It implies the construction of new urban areas and at the same time demolition in abandoned areas. With regard to the life span of water infrastructure, all actions taken now and in the near future will have an impact over five to ten decades. These circumstances place special demands on processes and technical solutions with regard to robustness, flexibility and mobility and require dealing with changes that cannot yet be foreseen.

Kiruna city has a population of 18 000 (Kiruna kommun 2014) and is located 145 kilometres north of the Arctic Circle. The climate is hence subarctic with short, cool summers and long, cold winters. Snow cover usually lasts from mid-October to mid-May, but snowfall can occur year-round. This makes the urban hydrological cycle complex and affects possible solutions for the management of stormwater and snowmelt runoff. In addition to the specific current climate conditions, climate scenarios predict rather severe effects for Northern Sweden compared to other regions in Europe (e.g. an increase of annual mean temperature by about 7°C until 2100 (SMHI 2014)).

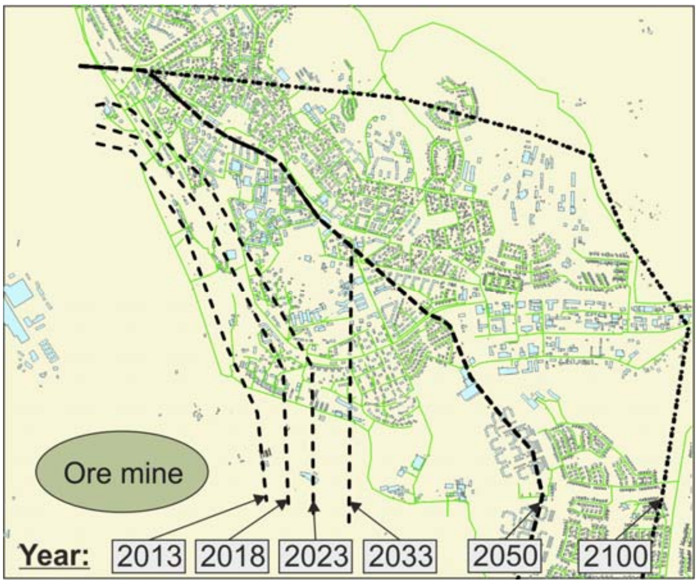

Figure 1. A part of the storm sewer network of the city of Kiruna and areas affected by expected deformations for different periods (dashed lines), storm sewer network (green lines).

Apart from various uncertainties, this transition provides a lot of opportunities for the implementation of new management strategies for stormwater and snowmelt runoff. This is also stated as a goal in the development plan formulated by the municipal executive board (Kiruna kommun 2014).

This work presents the approach developed in the joint interdisciplinary research project *Green/Blue Infrastructure for Sustainable, Attractive Cities*, designed to complement the on-going transitions of the entire water infrastructure in Kiruna. The focus of this paper is on the drainage system and its transition during the relocation process. For the purpose of validation and evaluation, some of the developed methodologies will also be applied in and learn from the cities of Zwolle (The Netherlands) and Innsbruck (Austria). These cities face different future challenges and have diverse possibilities for future development.

The approach can be divided in two main parts: 1) the development of a roadmap for the transition from a pipe based stormwater system to a more sustainable system providing also liveability in the new areas of the city, and 2) the support for systematic planning and assessment of the new drainage systems and infrastructure, including the transition period, and considering Kiruna's ambient conditions.

METHODS

Roadmapping

The opportunities and challenges facing urban managers are nowadays rather different from the past. Urban planning has moved into a very uncertain context for which, amongst other things, future climate, economics, population and citizen needs and expectations are difficult to predict. To tackle these uncertainties and turn them into opportunities, managers and planners need to think in ways different from the past. They now need to consider uncertainties and the effectiveness of infrastructure such as Green/Blue or drainage systems in the context of unknown performance in uncertain futures. There is a need to balance the longer-term (sustainability) with the more immediate (liveability for today's citizens). Therefore the selection of appropriate infrastructure to provide essential services and maintain the quality of citizen life requires careful consideration as to its' effectiveness in the short, medium and increasingly uncertain longer term. Fortunately alongside these uncertainties, the new perspective of ecological modernity, which brings nature and culture together in urban form, provides 'new'[1] and more resilient means of delivering many of these services, especially those related to water.

What is needed to bring this about is a means to meaningfully engage the key stakeholders in thinking about the longer term in a constructive way. Various methods have been developed to assist with the key stakeholder engagement process, including amongst others: guidance and papers on transitioning (Frantzeskaki *et al.* 2012; Ferguson *et al.* 2013) using case studies in Australia; methodology for use by water industry practitioners and researchers to facilitate strategic planning for a long term future providing guidance to develop a roadmap to bring about changes in practice in the EU project *PREPARED* (Rychlewski *et al.* 2013; Westling *et al.* 2014); development of a roadmap for sustainable drainage research needs for the UK water industry (Shaffer *et al.* 2014). Using these sources a framework has been developed for application in the presented project as illustrated in Figure 2. There are three phases A to C: starting with formulating a 'vision', or aspirations; considering drivers and consequences; moving on to potential responses tested against scenarios; with further input using a 'goals grid' process (Nickols 2015) to help identify where an organisation has practices that are supporting or opposing change, to ultimately develop the roadmap.

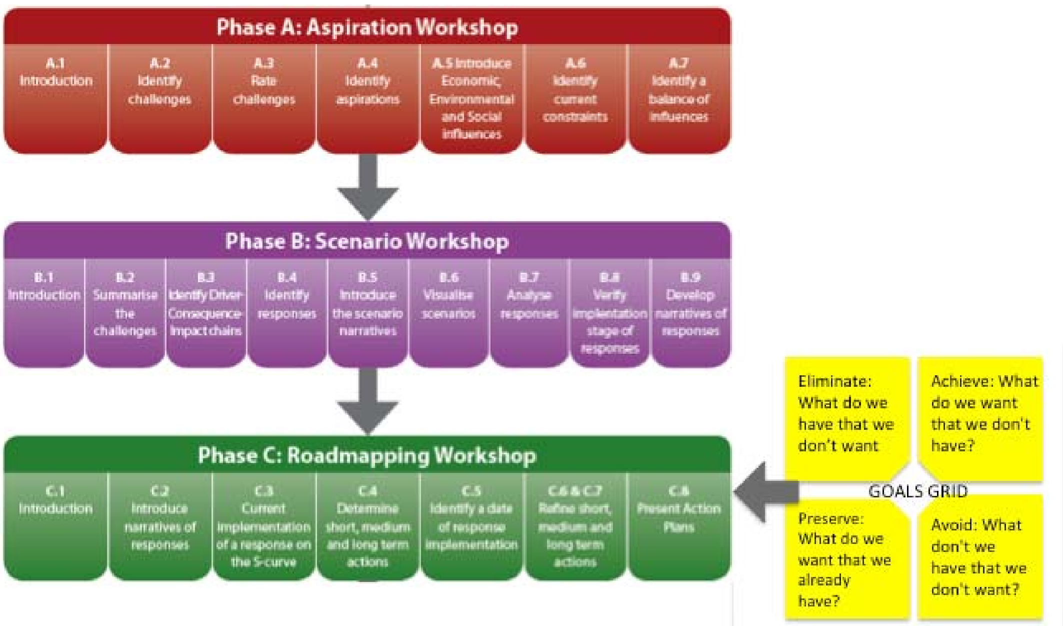

Figure 2: The key stakeholder engagement process – to develop a roadmap for bringing Green/Blue infrastructure into urban planning and design.

[1] In fact it is not new at all; rather a rediscovery of how things used to be done.

The presented project includes the exchange of knowledge with the City of Zwolle in the Netherlands, where there are initiatives to add further Green/Blue infrastructure to the City as part of major redevelopment. Two workshops have been held there to work through the processes in Figure 2. In the scenarios workshop, the Dutch *Delta II* program scenarios (Delta Programme Commissioner 2015) were used to test the responses against coherent visions of the future. The process of developing the roadmap is continuing and the equivalent process is now unfolding in Kiruna.

Systematic planning support

A model based approach is necessary to assess systematically and efficiently possible scenarios which are used to develop the roadmap. Existing methodologies addressing different aspects in the planning and transition process are adapted and extended substantially. These comprise 1) the transition of the water infrastructure networks from the current to the new city; 2) the placement of Green/Blue infrastructure in both, the newly built and existing (remaining) areas; 3) the performance of Green/Blue infrastructure in Kiruna’s ambient conditions and its implementation in the models; and 4) benchmarking the models for different scenarios (e.g. climate change, population growth or shrinkage, different configurations of the urban drainage infrastructure).

Existing algorithms to model possible transition scenarios of water infrastructure networks (e.g. Sitzenfrei *et al.* 2013) are being extended in order to consider the demolition of the drainage network in abandoned areas. These are used to generate multiple network layout scenarios for different transition states which are then subject to performance assessment. This allows the identification of critical points and periods in the transition process and, consequently, the critical scenarios (see Figure 4). All algorithms are being implemented within the open source scientific workflow engine “DynaMind” (Urich *et al.* 2012).

Bacchin et al. (2014) presented a systematic approach to identify potential locations for the placement of Green/Blue infrastructure in urban environments. This is based on both structural and spatially distributed biophysical input data, such as elevation and slope, soil properties, street network etc. This approach is being adapted and applied to the different scenarios, which also comprise different scales and portions of implementation of Green/Blue infrastructure.

To enable a sound and reliable consideration of Green/Blue infrastructure in the models, results from past and on-going research regarding the performance from laboratory and field scales serve as input to model improvements (e.g. Marsalek *et al.* 2003b). In addition to storm water runoff during summer, the drainage system must also handle snow melt runoff. Snow melt events are usually considered as significant with regard to volumes (and pollutant loads) (Marsalek *et al.* 2003a), which must be handled by the drainage infrastructure. Furthermore, soil is frozen during the snow melt season and the infiltration capacity can be reduced significantly. Different scenarios for snow management, climate and soil conditions are developed and then analysed using a snow melt model. The estimated melt runoff volumes can then be used as input to the other assessment methodologies.

RESULTS

First Stakeholder workshop

The eight participants of the first stakeholder workshop represented the core/inner circle of municipal actors directly involved in planning and management of urban stormwater, i.e. civil servants from the municipality and the public utilities company.

External challenges/drivers facing Kiruna's water systems. As a starting point for discussion in the workshop external challenges/drivers for changes facing Kiruna's water systems during the city relocation were shown, see Figure 3. To acknowledge Kiruna's ambitious vision of becoming a leader and role model of sustainability, three excerpts from the city's new comprehensive master plan (Kiruna kommun 2014) that speaks of the vision were shown to focus the participants' mindset during the workshop. Implications of Kiruna's challenges and visions were explored and discussed by the participants through a number of questions asked by the workshop leaders.

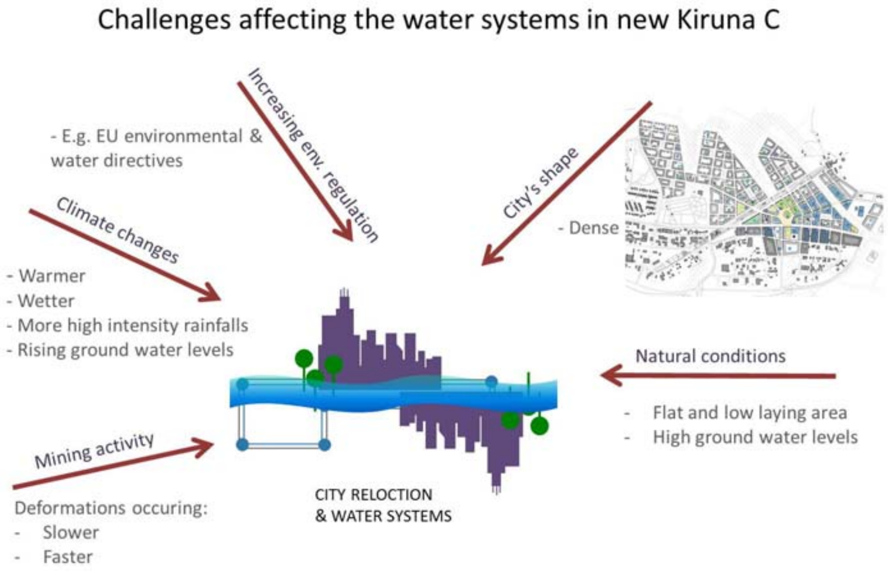

Figure 3: External challenges facing Kiruna's water system during the city relocation which might be exacerbated in future.

Key findings from the workshop are a set of guiding principles and core values that take into account both challenges and the city of Kiruna's vision.

<u>Guiding principles and core values</u>

1. to allow/follow natural waterways wherever possible (e.g. aim is to not hinder natural flows and build around naturally occurring water pools)
2. use nature mimicking/nature inspired solutions
3. use constructed solutions (e.g. pipes)

Stormwater should be viewed as a resource e.g. supplementing a natural river which has been cut off from its source due to the mining activities. Nature needs to be shown more respect and water must be allowed to flow where water wants to flow. Water should steer how and where the city is building and the city needs to adjust and allow space for water. Climate change and climate adaptation must be emphasised more. Green/Blue infrastructure and SuDs can aesthetically enhance the city's living environment.

Systematic performance assessment of water network transition

Figure 4 shows an example of performance evaluations of Kiruna's water infrastructure during the envisaged transition period for two scenarios of population development (constant, scenario 1; and growing population, scenario 2). The development of modelled system performance duing the transition process can highlight potential problems or possibilities for optimisation.

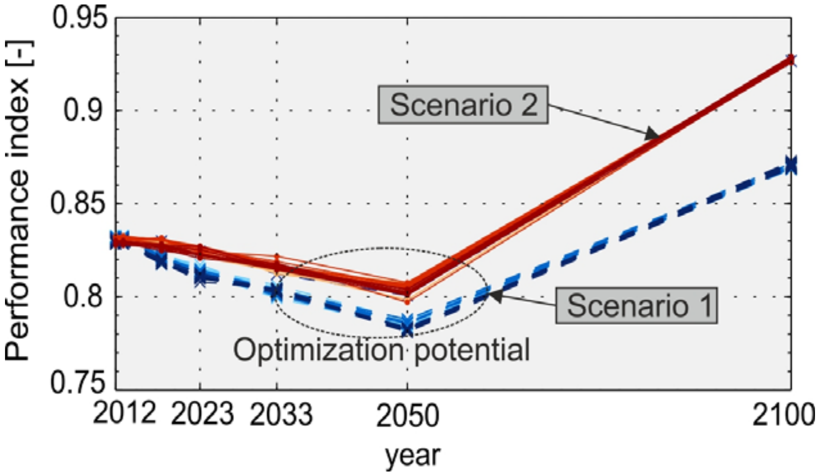

Figure 4. **D**rinking water age performance index during the transition process for two scenarios of population development.

Placement of Green/Blue infrastructure

The results of the structural analyses considering biophysical aspects are maps showing potential locations for the placement of Green/Blue infrastructure, whereof an example is shown in Figure 5. These maps are also suitable for further discussion and workshops with stakeholders during the planning process.

SUMMARY AND CONCLUSIONS

- The city transformation of Kiruna represents a very specific case of transition, due to the drivers as well as the climatic and ambient conditions. However, lessons learned from other cities provide important knowledge and suitable methodologies can be transferred and applied to the transformation process of Kiruna.
- Methodologies for both stakeholder involvement and systematic assessment have proven to be essential and suitable in other case studies and are therefore also applied in Kiruna.
- Kiruna's location and climate require the consideration of specific conditions and processes (frozen soils and snow melt), which also need to be implemented in the above mentioned methodologies and the planning of Green/Blue infrastructure.

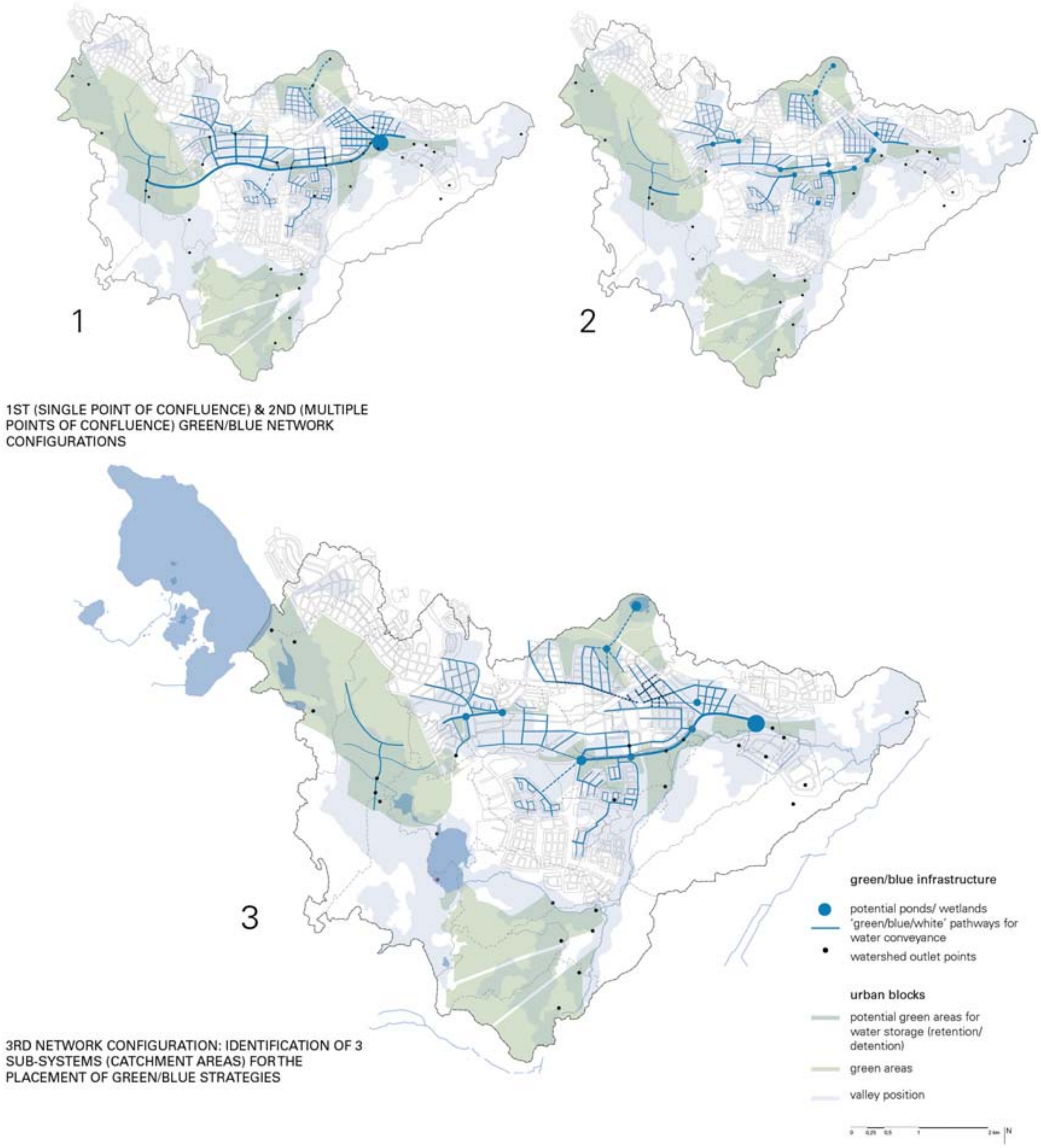

Figure 5. Green areas, streets and nodes suitable for potential placement of green/blue infrastructure in Kiruna in 2033, as a result of the systematic analysis.

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