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GREEN/BLUE CITIES:
Green/Blue Infrastructure for Sustainable, Attractive Cities

Combined Deliverable Report 2.3 and 2.9

Suggestions for stormwater management measures in Nya Kiruna: Green Street design

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Aim

The aim with this report is to present and discuss suggestions for possible implementation of stormwater control measures (SCMs) in the new city centre of Kiruna. The SCM alternatives were chosen based on technical requirements (retention and/or quality treatment) and aesthetical issues.

Method

The following suggestions for the implementation of stormwater control measures along selected streets in the new city centre of Kiruna were compiled based on meetings and discussions with the main stakeholders Kiruna municipality and Tekniska Verken I Kiruna AB (TVAB) as well as the consultant company SWECO. Participants were (*inter alia*) Eva Ekelund and Maria Persson (Kiruna municipality), Sofie Sarri, Mats Eriksson (TVAB) and Matthias Salomonsson (SWECO).

Further, a range of other deliverables prepared in the JPI Urban Europe project GreenBlueCities were used as input for these suggestions. These were mainly:

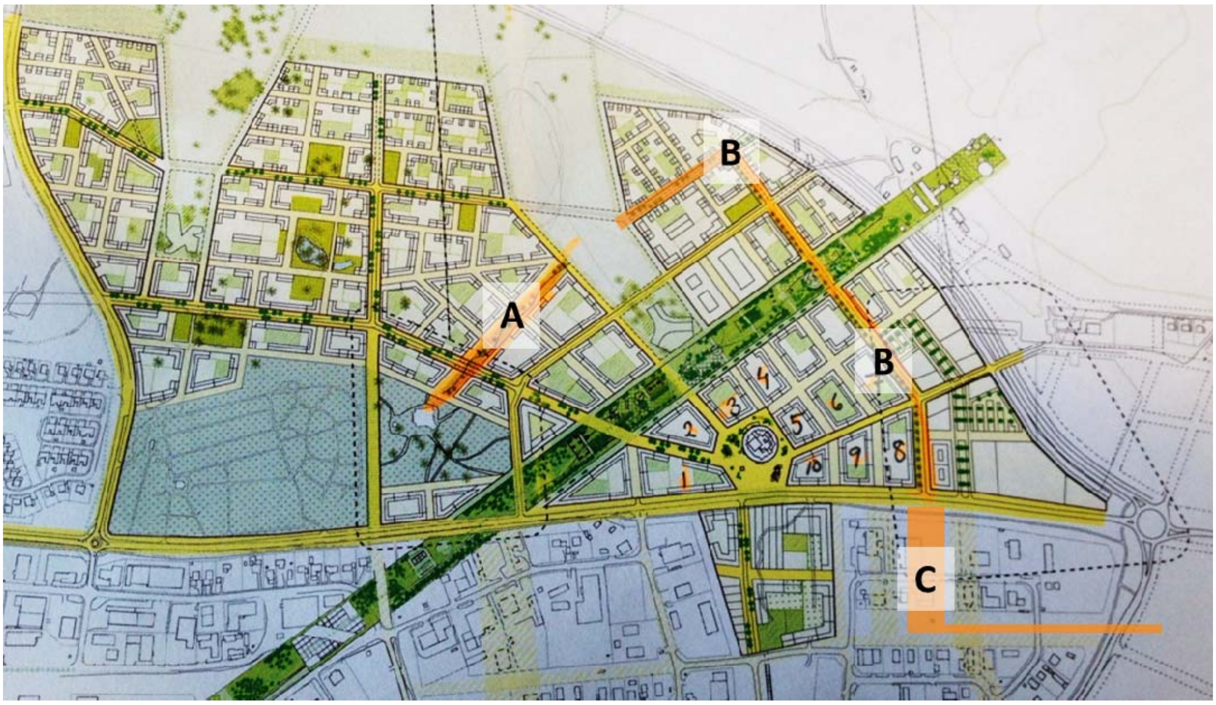
- deliverables 1.4: Future prediction of urban area development in Kiruna, Taneha Bacchin
- deliverable 2.2: Overview of smart special strategies and their effect regarding water management, landscape ecology, urban morphology, and quality of urban space of green/blue space adaptation in urban areas, Taneha Bacchin
- deliverable 3.3: Function of SCM in cold climate regions, Godecke Blecken

Site description

According to Kiruna municipality and TVAB SCMs are supposed to be implemented along the orange marked streets in the new city centre. Section A and B have widths of 33 m and 25 m, respectively.

Result

Given the pre-conditions from the existing layout plan, the stormwater management system is a linear, cascading system leading the water towards the “green finger” between section A and B or downstream section C.

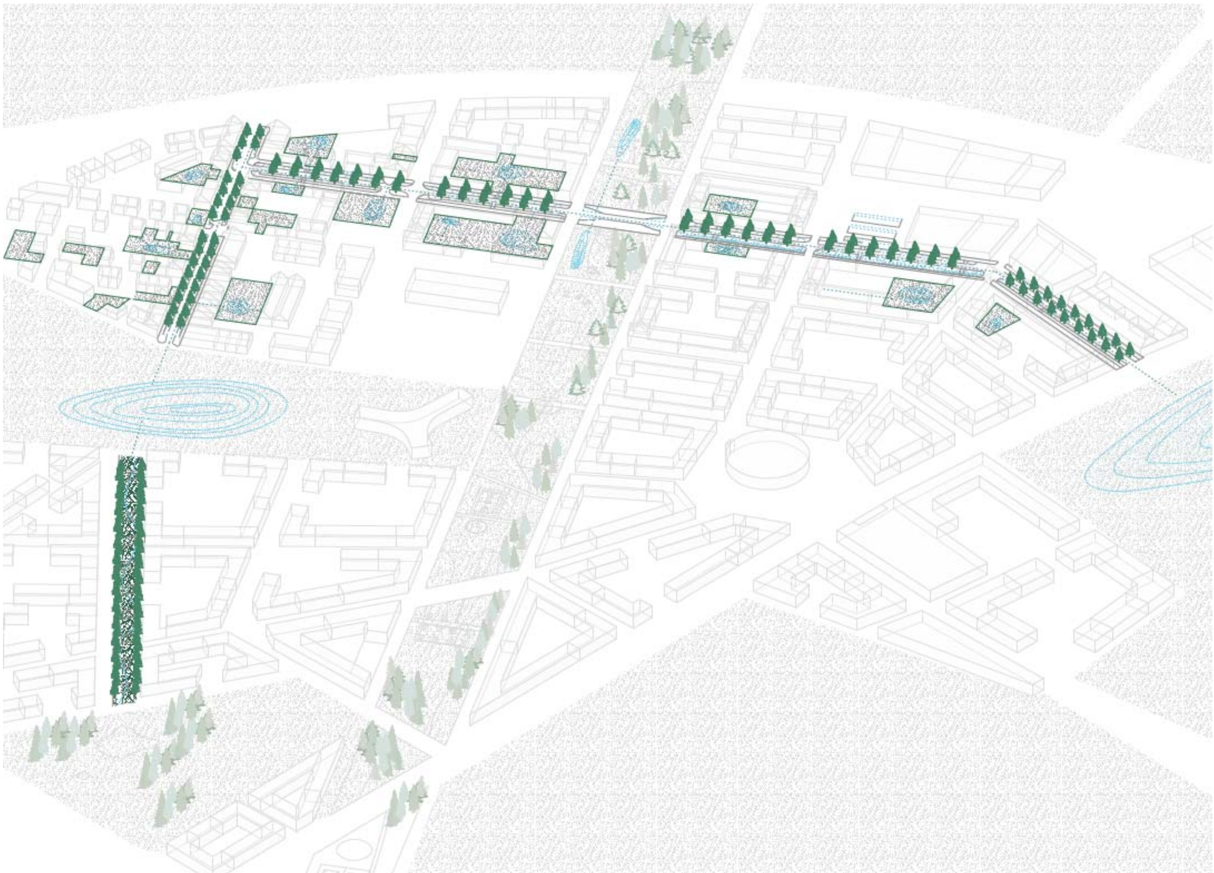


The suggested facilities can manage rain events with different intensities as described in the following. Storms within “Domain 1” are so called “everyday rains”, “Domain 2” includes the design rains and “Domain 3” storms exceeding these design rains. This approach is suggested in P110 by the Swedish Water Association and internationally, e.g. by Digman C., Ashley R

M., et al (2014). Managing urban flooding from heavy rainfall – encouraging the uptake of designing for exceedance – Recommendations and Summary. CIRIA RP991.

Stormwater management strategy

In this proposed alternative the focus is on quality treatment along the streets in bioretention cells The water quality treatment takes place in the linear structure along sections A and B.



Section A

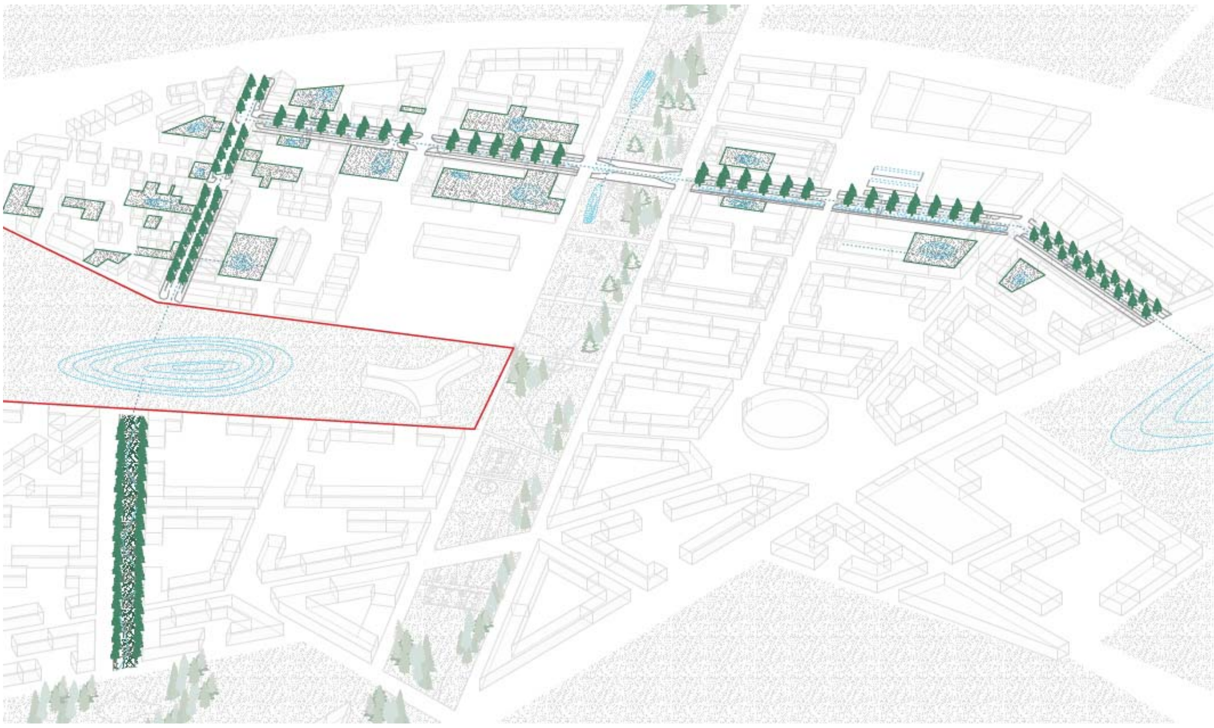
Section A is wider (appr 33 m) and less urban. Historically significant buildings from the existing Kiruna will be relocated to this street. The proposed SCMs underline the park character.

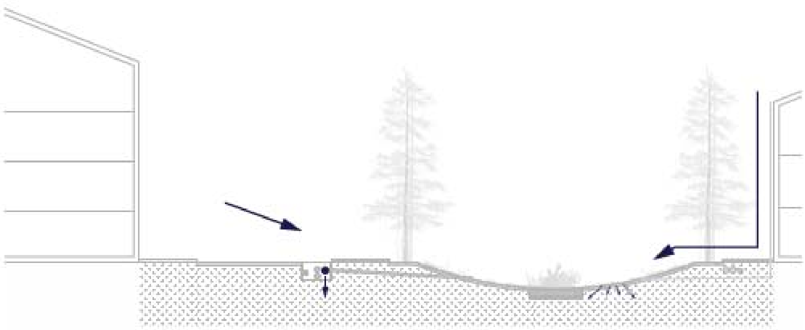
The basic structure is a **swale** meandering along the street. It conveys the water to **bioretention cells,** which are placed along the swale. In these cells, the stormwater infiltrates and is treated. Since bioretention cells cannot infiltrate the runoff from intense storm events, in such cases the excess water is conveyed through the system further downstream to a vegetated depression in the green finger which serves as a **detention facility**.

The **swale** serves as a pre-treatment system which reduces sediment loads on the bioretention cells and thus the clogging risk. The treated water is collected in a drainage pipe and discharged to a parallel storm sewer. The swale can be used for snow storage in winter.

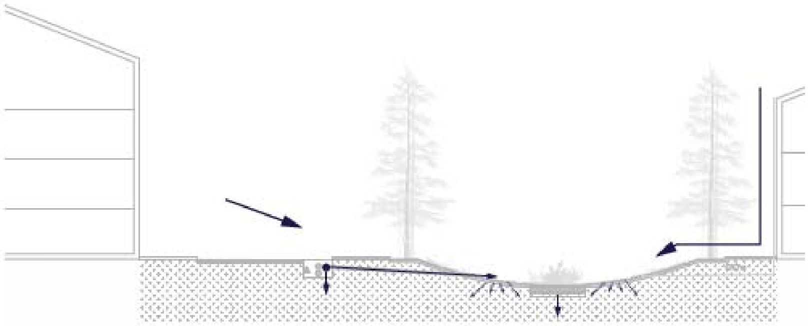
The **bioretention facilities** treat the water by bio/geochemical processes in the filter material. A coarse filter material is recommended in cold climate applications to avoid water standing in the system when temperatures drop below zero. Vegetation has a beneficial effect on the treatment, on maintaining the infiltration capacity and can provide aesthetical values. The vegetation must be adapted to the local climate. Often it is recommended that no snow should be stored on these facilities.

The **detention facility** only fills during intense rains and can thus be designed to fulfill other (e.g. recreational) purposes during dry weather.

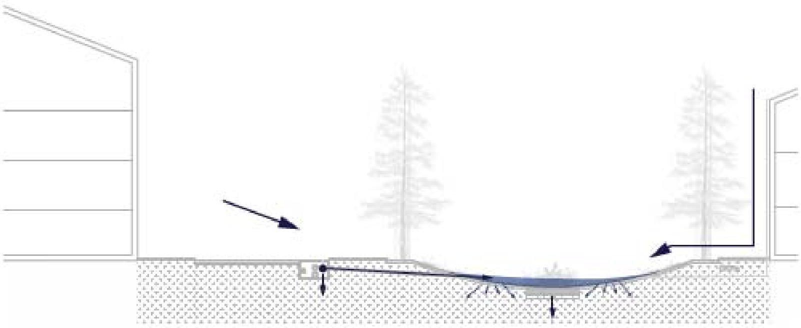




Domain 1: Bioretention, swale



Domain 2: Swale, detention basin, overflow/bypassing in bioretention

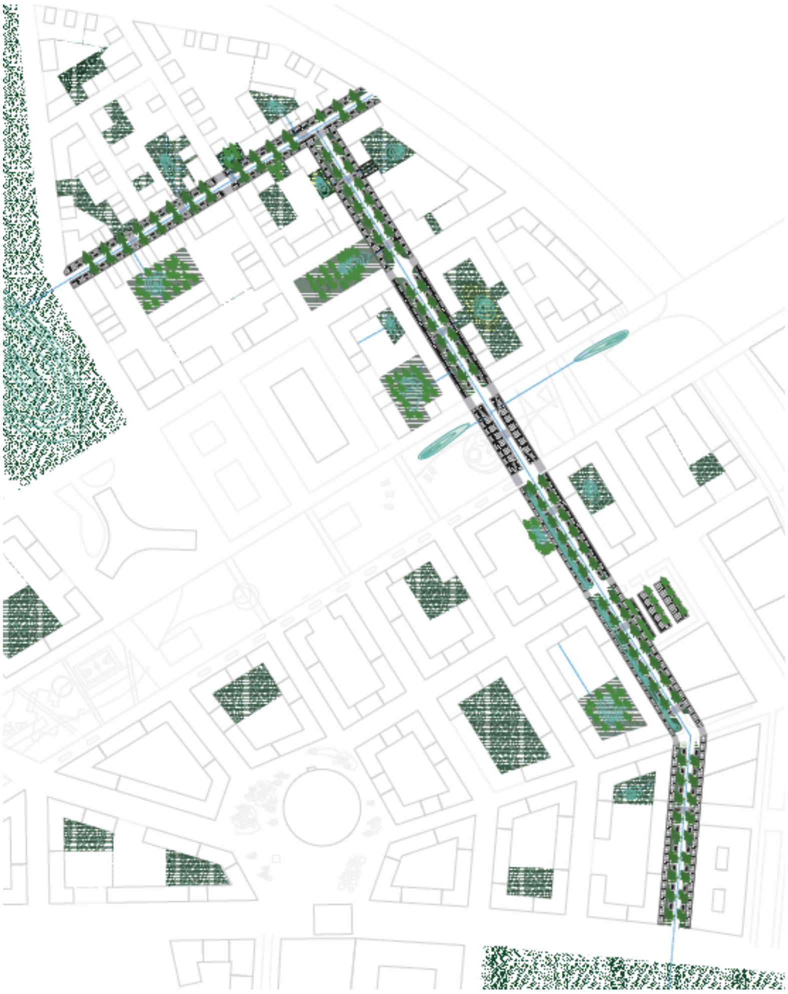


Domain 3: swale, detention basin, water flow probably occurs on street surface.

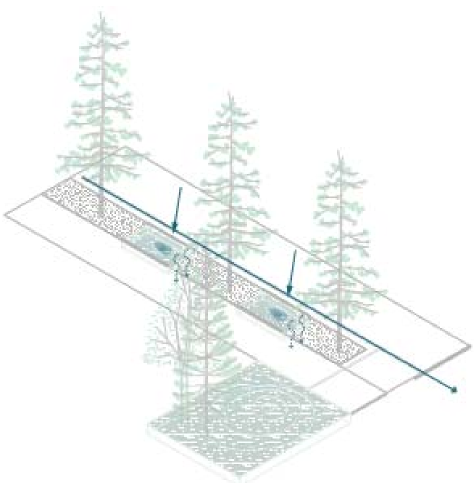
"Inspiration pictures" for section A:
Meandering swale   bioretention cells in swale   detention facility during dry weather
Source: Stahre, 2008; Melbourne Water, 2005; own picture.

Section B

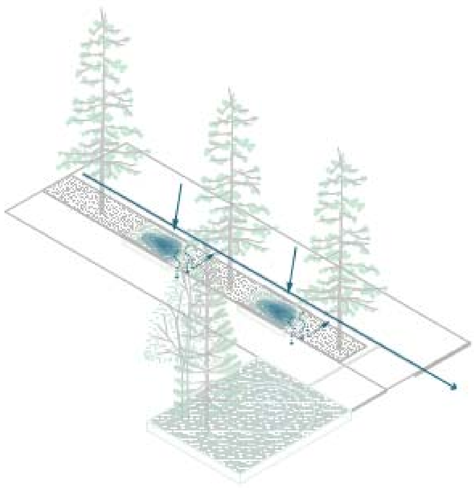
Section B is narrower compared to section A and consequently less space for SCMs is available. The proposed bioretention cells underline the urban character.



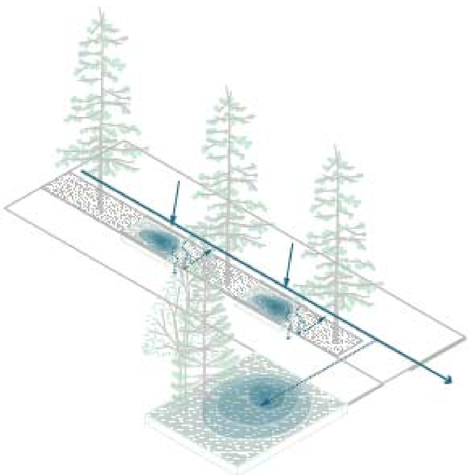
The basic structure is a cascading **bioretention** cell system. The system's function is the same as for the bioretention swale described above. Given that no sediment pre-treatment is provided, the cells shouls be equipped with a small sediment trap. Snow should not be stored on the bioretention cells to avoid clogging of the systems.The filtered water / bypassed water after intense rains is discharged to a pipe system and conveyed either to the detention basin in the green finger or towards system C in the south.



Domain 1: Bioretention



Domain 2: pipe system, detention basin, overflow/bypassing in bioretention



Domain 3: detention basin, water flow probably occurs on street surface.

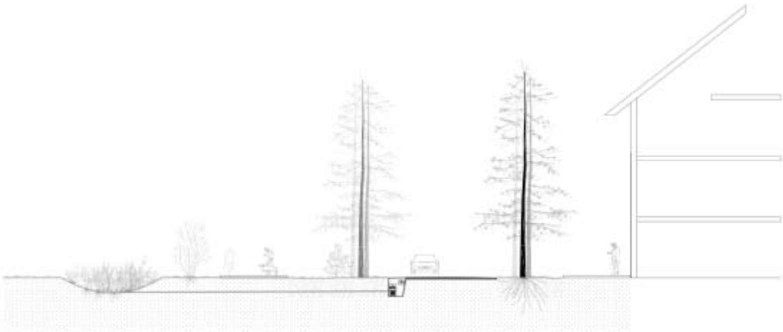
"Inspiration pictures" for section :
Bioretention cells in dense urban environment

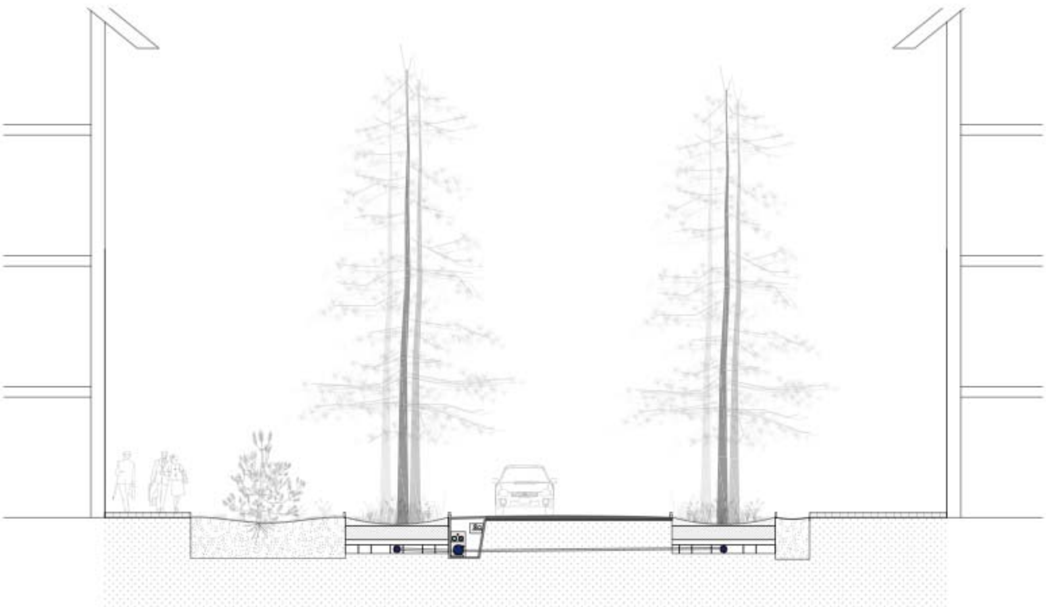
Technology, in section B

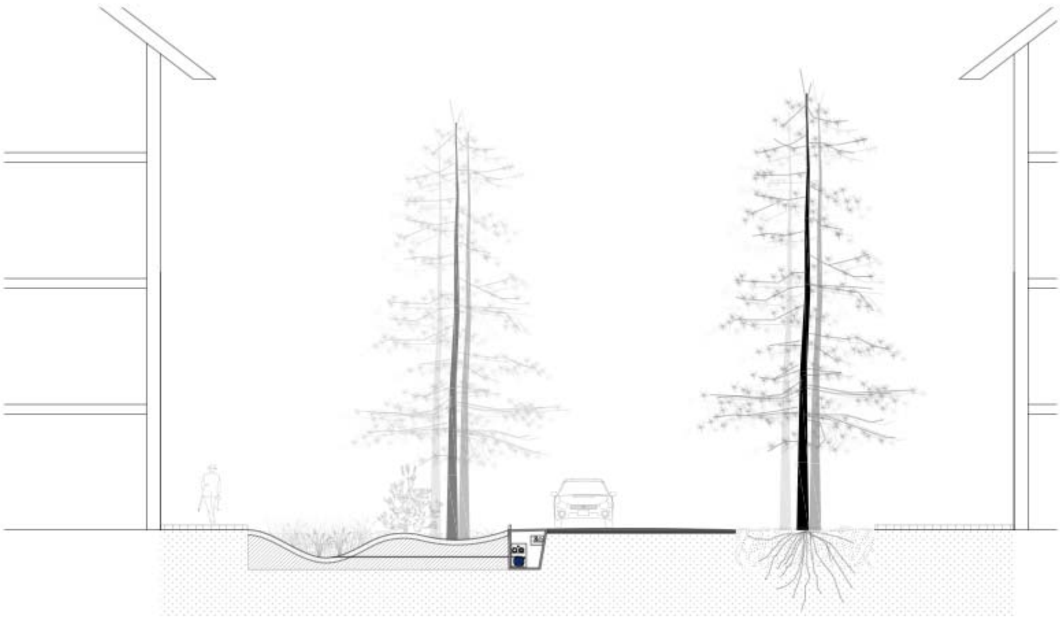
Technology Section drawings shows the changing and dynamic nature oh hybrid green-blue grey infrastructures in terms of surface design and subsurface content and linkages. As explained in the methodology the design output is informed by the plan composition and the geomorphological condition of the site.

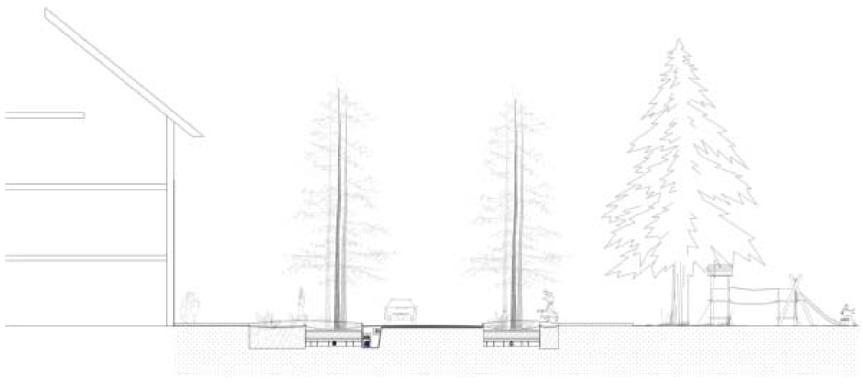
The following images shows the technological section, which becomes operational and performative for snow and rainwater management. A series of drawings shows the changing technologies and the subsurface – surface interdependencies involved in the projection of hybrid green-blue-grey infrastructures.

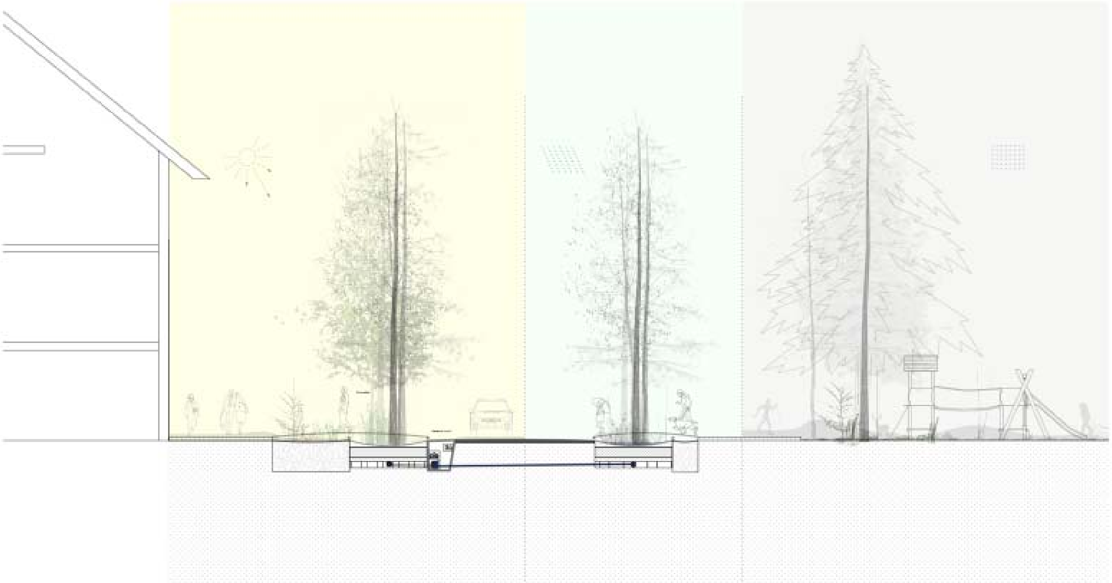
Secondly the three last drawings shows the dynamic and ever-changing nature of green-blue infrastructures and their ability to host, accommodate and facilitate a multitude of socio-climatic contingencies.

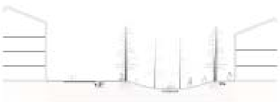


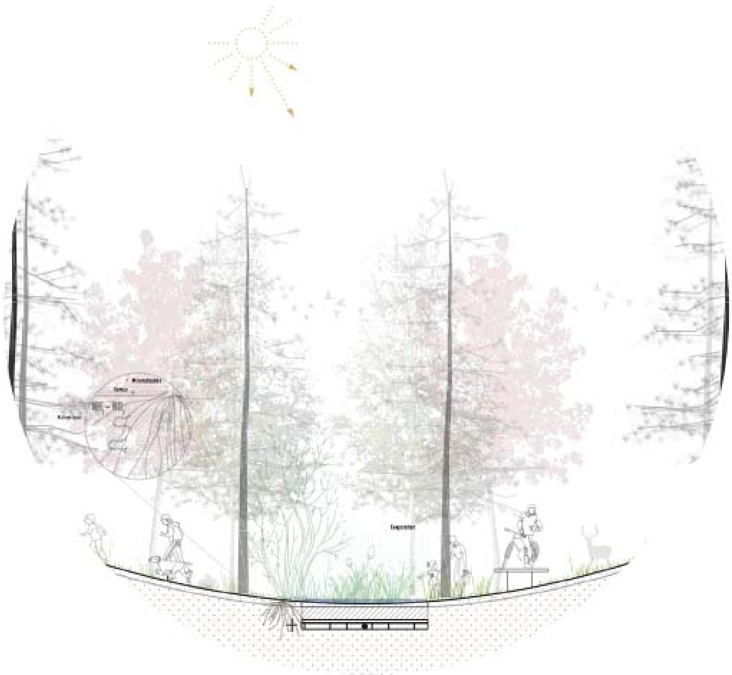


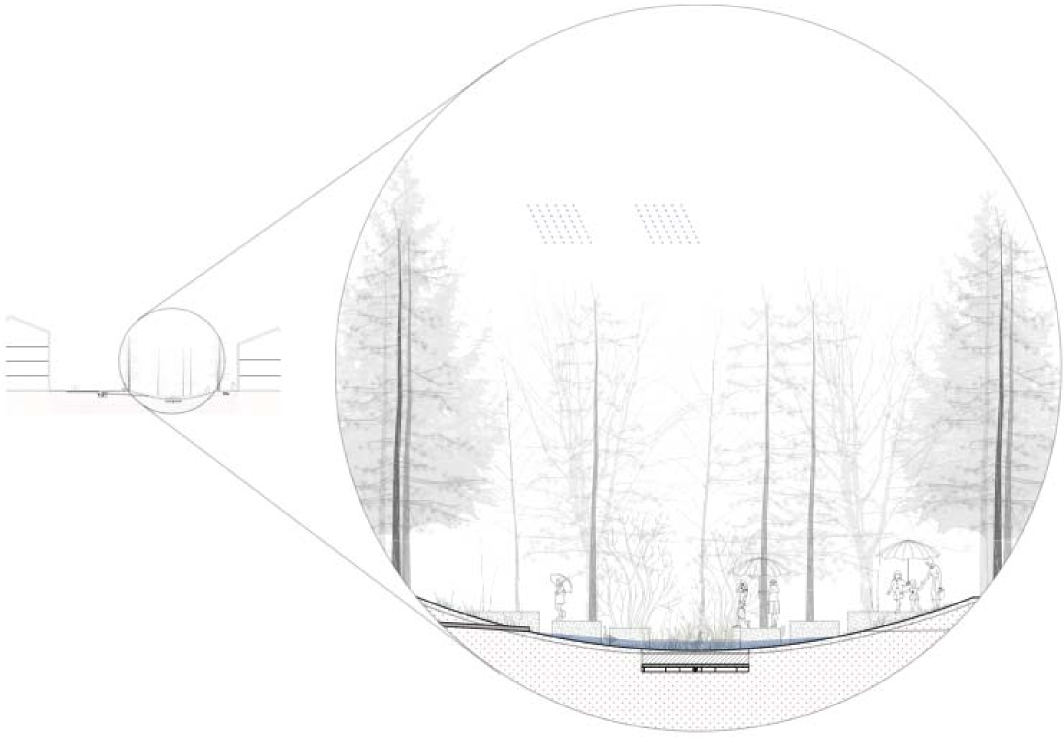












Simplified hydrological assessment of Pilot A

In the context of the preparatory study on the integration of Green/Blue structures in the future stormwater system of Kiruna City, the ”Green Street Design” – Pilot A(see Figure 1) was subject to a simplified assessment. The goal was to evaluate the hydrologic function in the “Domain 3” (i.e. storms exceeding design rains rainfall events – see above), i.e. if runoff can be conveyed on Pilot A’s surface without causing damage. Due to limited data availability on the stormwater drainage system, the results can only be considered as preliminary. In order to consider uncertainties due to limited knowledge of the system, conservative assumptions were made throughout the assessment process.

The range for exceedance rainfall was defined based on the planned land use surrounding Pilot A, which is dense residential. The drainage system in these areas should convey runoff from rainfalls up to a return period of 20 years without flooding (total pressure head in pipes below ground level). Exceedance rainfall up to a return period RT of 100 years should be conveyed on the surface without causing damage to buildings and infrastructure.

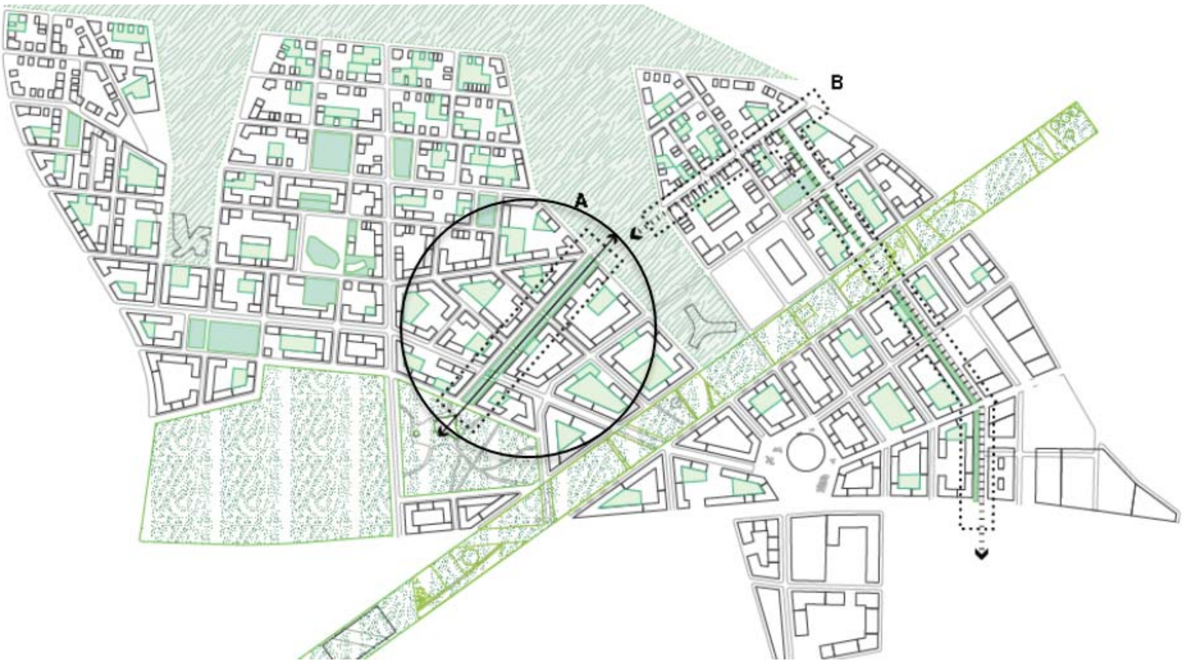


Figure 1: position of the pilot in the new city centre of Kiruna

Materials and Methods

The catchment assumed to contribute with surface runoff is shown in Figure 2, and has an area of 32.46ha with an average imperviousness of 22%.

Figure 2: Catchment area (blue polygon) assumed to drain into and discharge via the pilot, respectively.

Due to the expected large runoff volumes and the low permeability of the native soil (Moraine/silt loam, saturated conductivity 3.8mm/h), the pilot is expected to function mainly as a retention and conveyance structure, and infiltration being of minor importance. Therefore, the Manning equation can be used for a first assessment of the flow capacity. For this purpose, the cross section of the Pilot street can be approximated by a trapezoidal shape (see Figure 3). The discharge Q and average flow velocity V for a flow depth of 2m (in the centreline) and different channel slopes and side slopes are summarized in Table 1. At full depth, the channel can convey considerable discharges, but with high flow velocities with regard to safety for people.

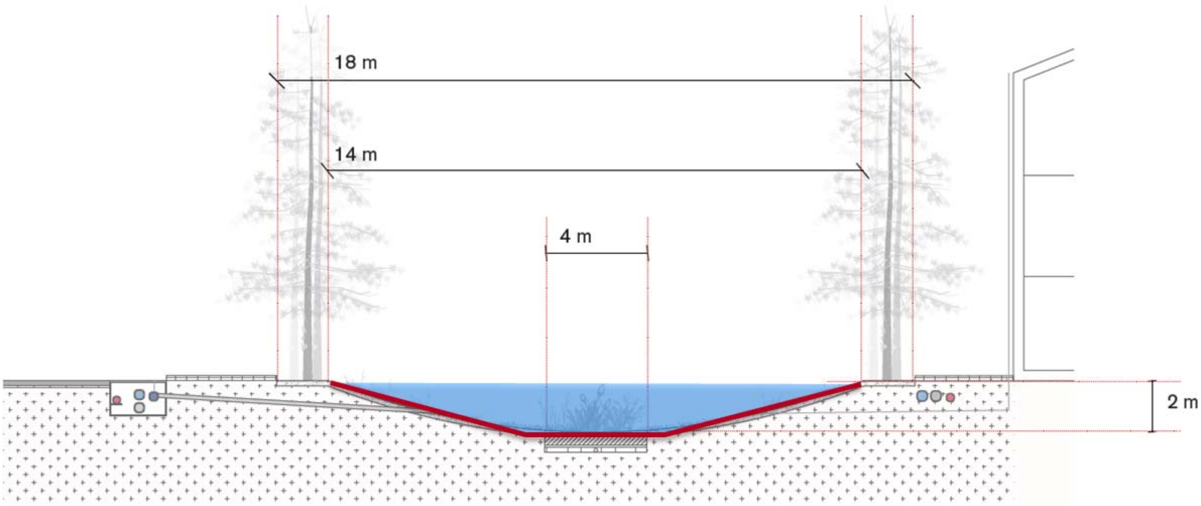


Figure 3: Cross section of the suggested street design of Pilot A, showing the dimensions of the possibly available flow area, which can be simplified by a trapezoidal channel.

Table 1: Discharge Q and average flow velocity V obtained with the Manning equation for a trapezoidal cross section with 2m flow depth, 14m water surface width, and a Manning value of 0.25.

Channel slope	**Side slope**	**Bottom width in m**	**Q in m^3/s**	**V in m/s**
0.01	3.5:1	0	5.4	0.39
0.01	2.5:1	2	8.2	0.46
0.005	3.5:1	0	5.8	0.32
0.005	2.5:1	2	3.9	0.28

In a next step, the model EPA SWMM 5 was used for an assessment of expected surface runoff from the catchment area (Figure 2) and the Pilot A's performance. The discretization of the catchment area into subcatchmnets is shown in Figure 4. The stormwater sewer system, supposed to drain runoff from rainfall events with RT ≤ 20 years without flooding, was not considered in the model. In the context of a preliminary study, this can be interpreted as an additional safety factor.

The street where Pilot A is located is represented by a subcatchment and several LID-objects connected in series, as presented schematically in Figure 5. The subcatchment represents the impervious area, the areas with porous pavement and a small share of permeable (green) area. Runoff from this subcatchment is routed into a swale, which drains into a bio-retention facility. Overflow from this facility is routed into another swale, while the drain outflow is routed directly to the outlet. This is a simplification of the cascaded system of swales and bio-retention cells. Furthermore, the model routes all runoff through the entire system, while in reality it would receive longitudinal and lateral inflow.

Figure 4: Discretization of the catchment area into subcatchments and their hydrologic connection for modelling with EPA SWMM.

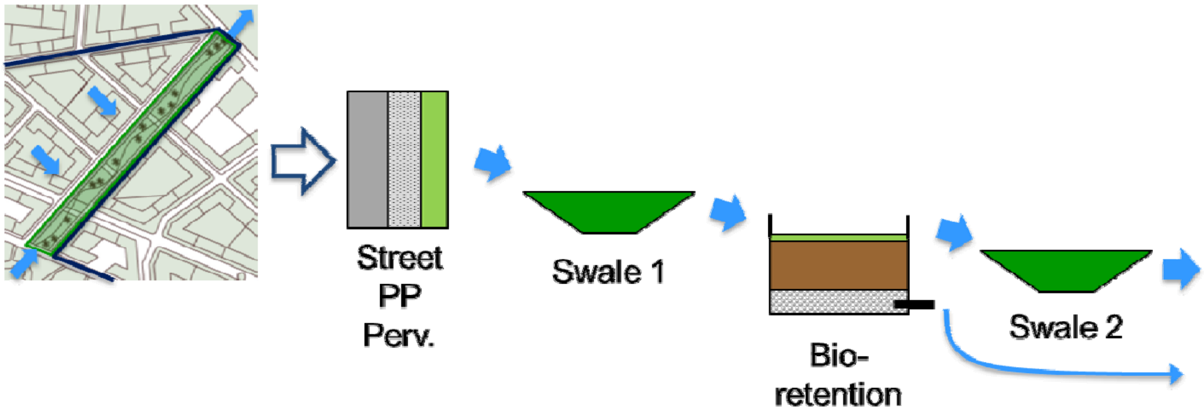


Figure 5: Representation of Pilot A in the model placing a subcatchment and different LID-objects in series.

As rainfall input, a block rain (constant intensity) with RT = 100 years and 15 minutes duration, was used. The intensity was determined according to Swedish guidelines. A climate change factor of 25% was applied to the rainfall intensities. Table 2 shows rainfall intensities and volume for different return periods.

Table 2: Rainfall intensities and volumes according to Dahlströhm's Equation considering a climate change factor of 25% (Swedish guideline P110).

Return period in years	Duration in min	Intensity in mm/h	Total volume in mm
20	15	102.16	25.54
100	15	174.06	43.52

Results

Figure 6 shows simulated in/outflows to and from the different model objects representing Pilot A. It also includes the total surface runoff entering the facility, as well as the total outflow.

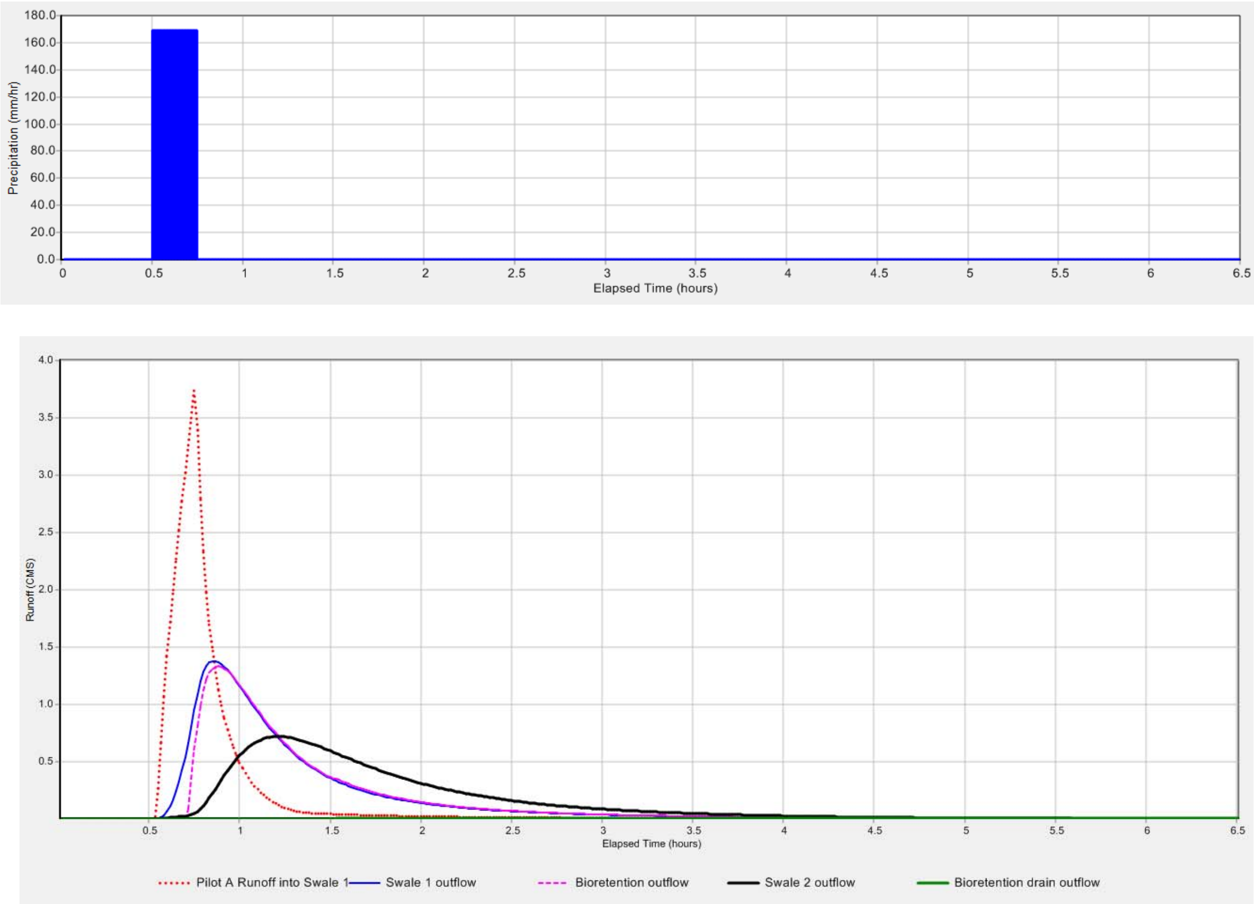


Figure 6: Rainfall input (top) and runoff (outflow) from the different model-objects (subcatchment, swales, bio-retention) representing Pilot A.

The total runoff volume is $3.24 \cdot 10^3 m^3$. The subcatchments infiltrate between 25 and 83% of the precipitation, whereas the swales only infiltrate 1.2 – 1.9% of the inflow.

Conclusions

The suggested design for Pilot A has the potential to convey surface runoff for the investigated design storm event (15 minutes, RT = 100 years) without damage and a maximal water depths of 1.55m. However, as indicated by the first assessment using the manning equation, relatively high flow velocities might occur. Furthermore, the actual outflow condition might be different from the assumption in the model (free outflow), and backwater might occur.

Another limitation of this assessment is the missing analysis for different rainfall durations. This might be of importance considering the large amount of pervious areas, which might contribute more surface runoff once their infiltration capacity decreased due to saturation.

Results confirm the assumption that the main function of Pilot A is flow retention and conveyance, as infiltration is of minor importance.

For detailed design, better data to delineate the contributing catchment area as well as a more detailed model for surface runoff would be needed.

Acknowledgements

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