Future changes affecting hydraulic capacity of urban stormwater systems

Karolina Berggren*, Axel Lans**, Maria Viklander*, Richard Ashley***

*Luleå University of Technology, Sweden
**Vatten och Miljöbyrån, Luleå, Sweden
***University of Sheffield, UK, University of Bradford, UK,
UNESCO IHE Delft, Netherlands, and Luleå University of Technology, Sweden

LULEÅ UNIVERSITY OF TECHNOLOGY

Integrated urban drainage modeling in the early stage of master planning

Overall objective

UD models - possible tools to use early in the planning processes and thereby increase the ability to create and maintain a healthy sustainable urban environment.

Overall objective

UD models - possible tools to use early in the planning processes and thereby increase the ability to create and maintain a healthy sustainable urban environment.

Second objective

Study the impacts of future changes on hydraulic capacity of an urban stormwater system, using a simple sensitivity analysis on a small catchment in Luleå, Sweden.

- Three factors tested:
  - Urbanization - as increased rate of imperviousness;
  - Climate change - as increased intensity of rainfall;
  - Pipe deterioration - as roughness in the pipes (k-value) and changed pipe cross-sectional area.

Urban drainage system - Invisible

The urban drainage system is ”not existing” as long as it works ……

The urban drainage system is
”not existing” as long as it works ……

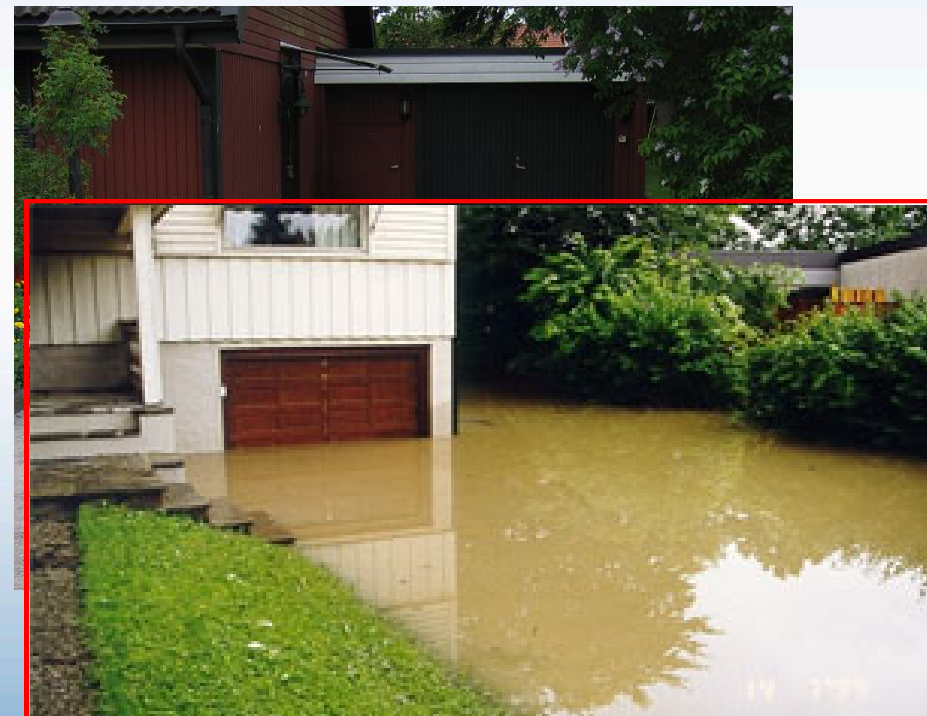
Taken as granted

The urban drainage system is
”not existing” as long as it works ……

Taken as granted

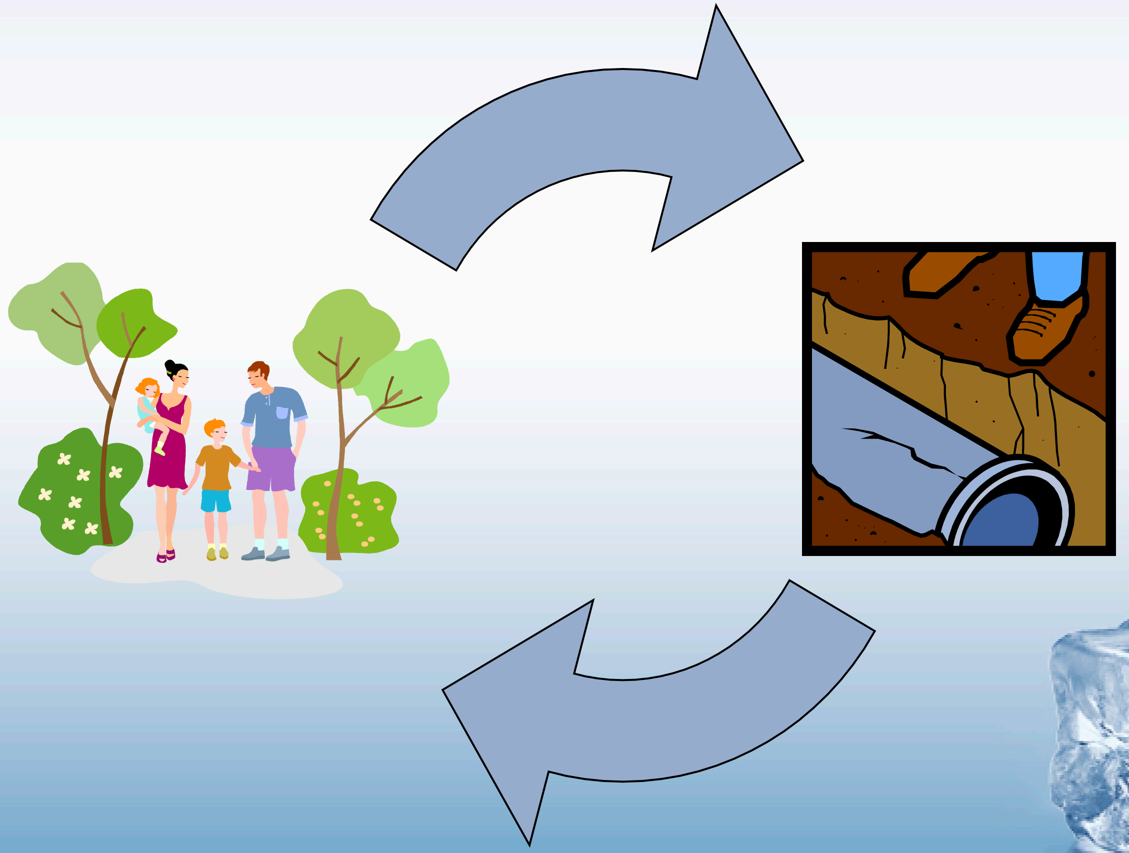
Problem!!

But ……….



Socio-Technical system

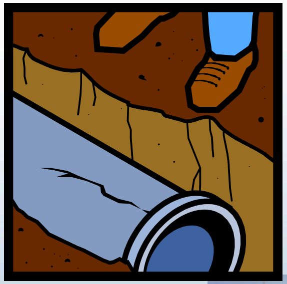
Urban drainage systems
Socio-Technical system



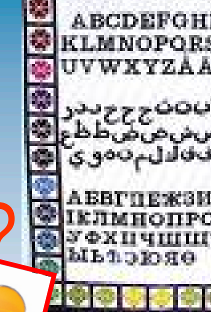
Responsibility - Ownership

Who is responsible/owns the urban drainage?

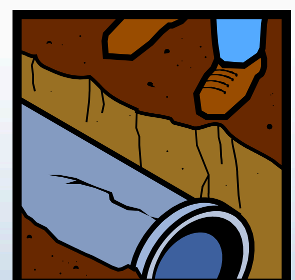
Municipality departements
Urban water
Street
Park
Environment
Road authories
County administration
Property owners
Households



Who is responsible/owns the urban drainage?

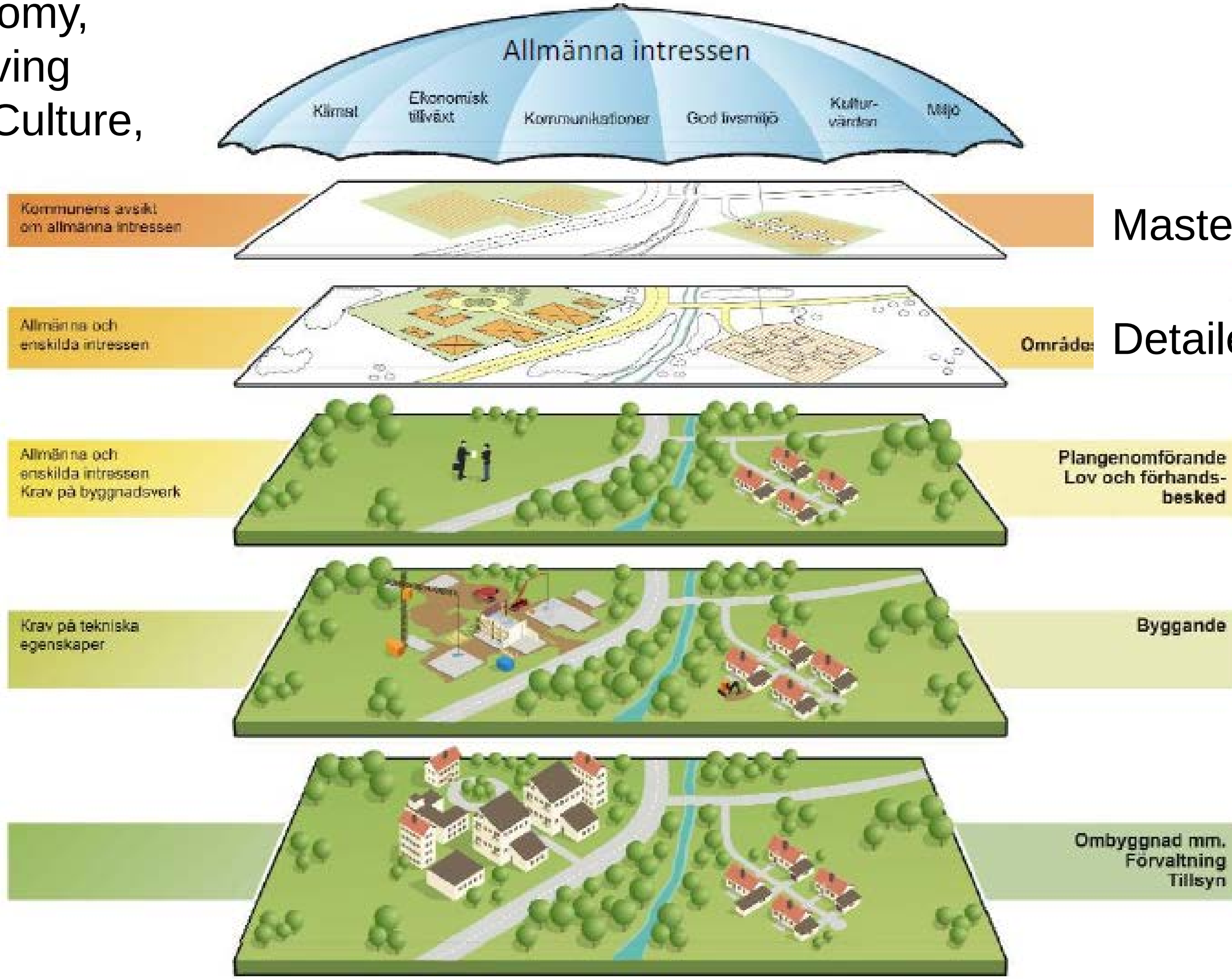


- Municipality departements
- Urban water
- Street
- Park
- Environment
- Road authorizes
- County administration
- Property owners
- Households



Swedish National Board of Housing, Building and Planning

General aspects, e.g Climate, Economy, Transports, Living environment, Culture, Environment



Master plan

Detailed plan

Figur 3. PBL-systemet från översiktsplan till genomförd plan (NYAPBL, 2011).

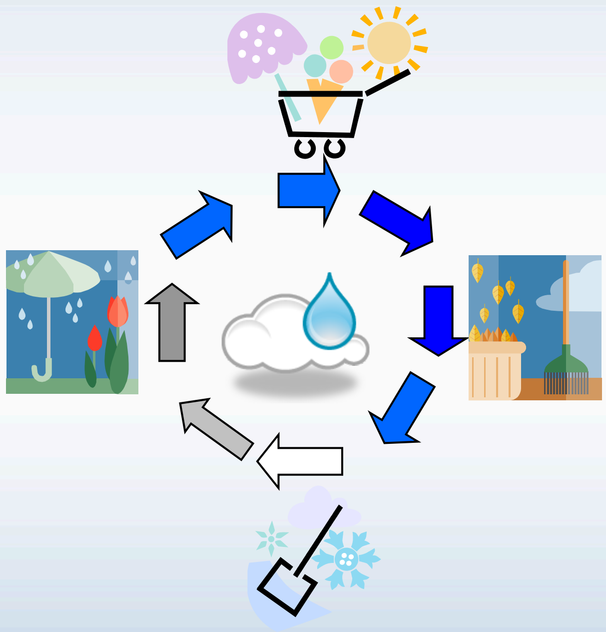
Variations - Changes

LULEÅ
UNIVERSITY
OF TECHNOLOGY

UW

UW

UW



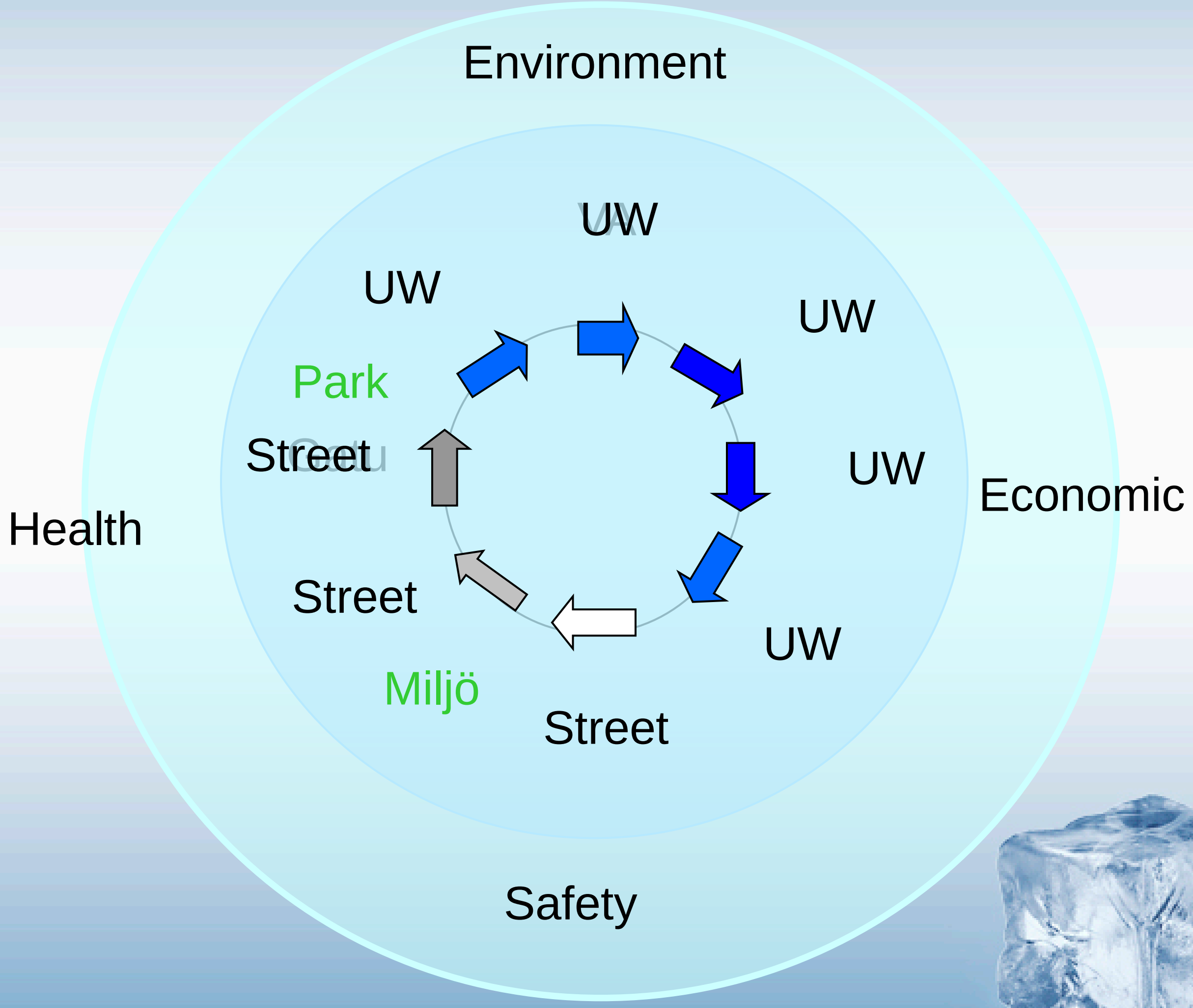
Street

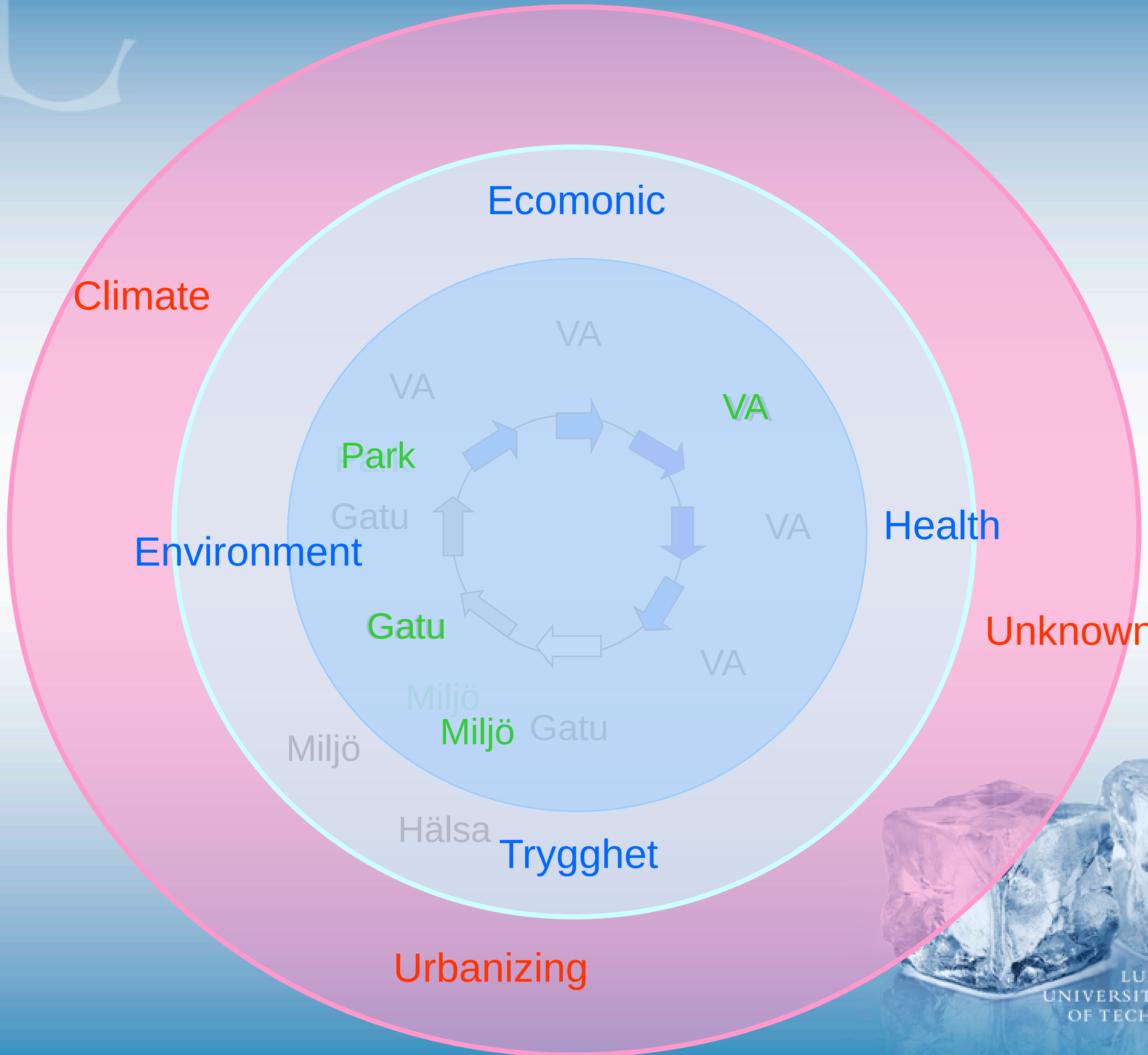
UW

Street

UW

Street


Environment
UW
UW
UW
Park
Street
UW
Economic
Health
Street
UW
Miljö
Street
Safety


Ecomonic
Climate
VA
VA
VA
Park
Gatu
VA
Health
Environment
Gatu
Unknown
VA
Miljö
Miljö
Gatu
Miljö
Hälsa
Trygghet
Urbanizing

Challenges

Changes

1900 2000 2100

Challenges

Changes…..

1900 2000 2100

Health

Controlled runoff – ”Dry shoes”

Resource!!!

Esthetics – Added values

Environmental issues – Dead fishes……..

The largest problem?

Lack of consensus in the urban drainage – urban water

- -Fragmented and inconsistent solutions
- -The water comes up on the table when everything is already clear

LULEÅ UNIVERSITY OF TECHNOLOGY

24

Summary – Up to today

Planning level

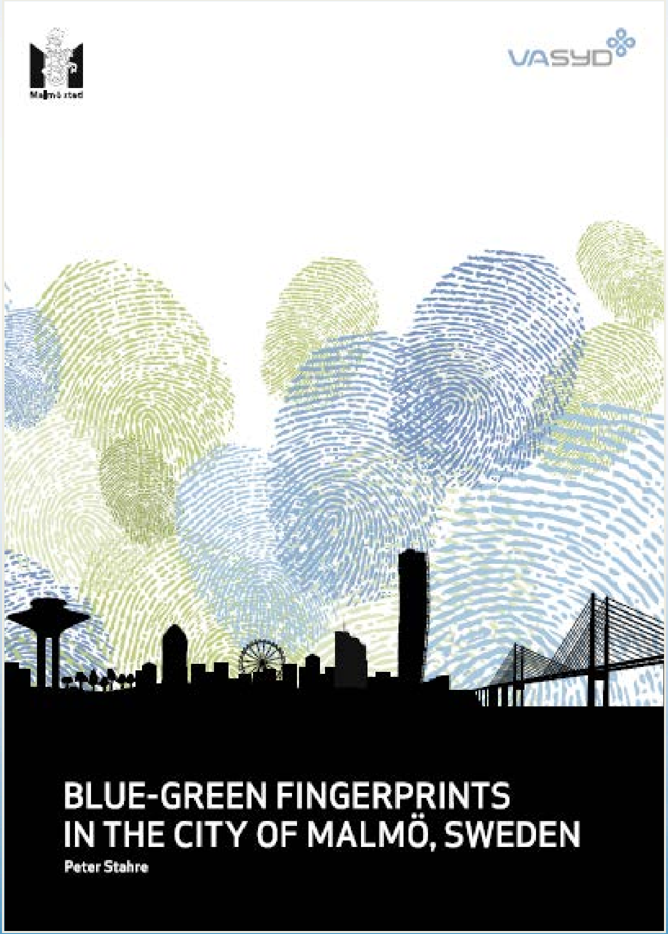
- UD models may be useful during the master plan discussions – ex visualization will improve the understanding of the situation
- Different types of scenario's were discussed easier – including urbanization, climate change pipe conditions

Technical level

- All scenario's (urbanization, climate change pipe conditions) affected the hydraulic capacity in the existing UD system, most important was the pipe conditions.

LULEÅ UNIVERSITY OF TECHNOLOGY

Blue-Green fingerprints in the city of Malmö, Sweden
P Stahre, 2008



The transition from a traditional urban drainage towards a more sustainable drainage concept is a long process. When you enter the path of sustainable urban drainage it will soon become obvious that the institutional barriers between the different stakeholders involved in the planning and implementation of the facilities often are unexpectedly high. For most people in the city administration it is much more comfortable to remain on more well known and reliable paths. To try new approaches is always associated with a certain risk. If you are not willing to take these risks and don't want to make any mistakes, it is probably better stay away from sustainable urban drainage.

Thank you!

Study area

- Aurorum, Luleå, Sweden
- Business/Industrial area close to the university, including three houses for student living

Larger catchment

Black: study area
Red: Area for new development

LULEÅ UNIVERSITY OF TECHNOLOGY

- The catchment is 7.7 ha
- UD system built in 1988, with 72 nodes and pipes.
- Imperviousness: 49% (total), for smaller area already developed (4.7 ha) the rate is 80%.
- Model: 1D/2D MikeFlood (MikeUrban and Mike21) by DHI (2011).
- Grid sizes of 2x2m

Small scale sensitivity analysis

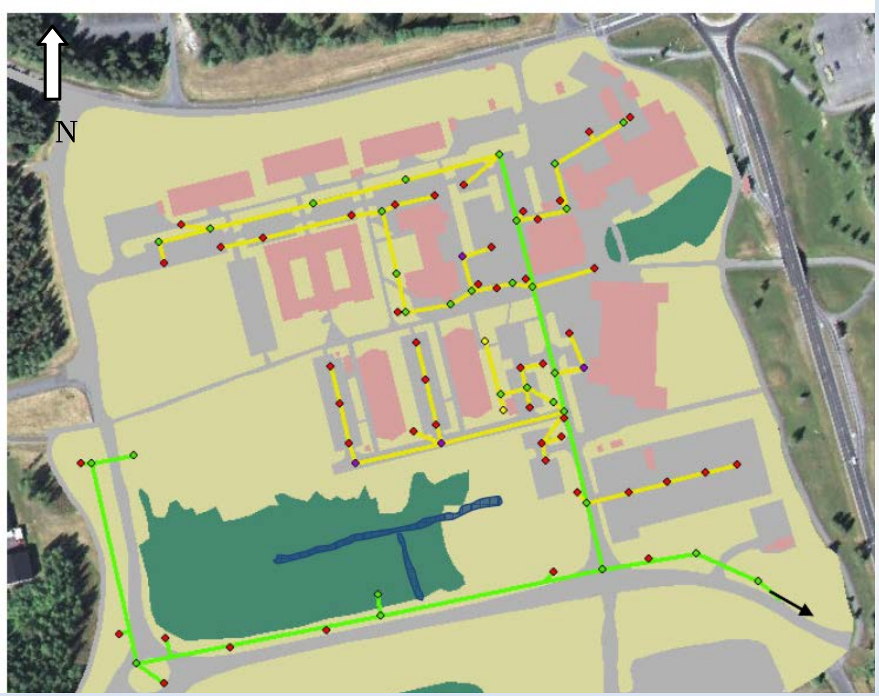
- **Baseline scenario:** existing system, historical rainfall statistics.
- **Group 1:** Three future scenarios, Urb, CC and Pipe system changes, varied in single steps
- **Group 2:** Combined factors: impact from pipe system deterioration tested
- **Group 3:** Extreme scenario: Rainfall of 100 year return period and urbanization with worst case of pipe deterioration.

Small scale sensitivity analysis

Group	No	Urb [%]	CC [%]	Pipe k [mm]	Pipe CSA [-]	Rainfall, and RP
Baseline	0	-	-	3	-	Block, 10y
1	1	***80***	-	3	-	Block, 10y
	2	-	***20***	3	-	Block, 10y
	3	-	-	***6***	***1/3*D***	Block, 10y
2	4	80	20	***3***	-	Block, 10y
	5	80	20	***6***	-	Block, 10y
	6	80	20	6	***1/3*D***	Block, 10y
3	7	80	-	6	1/3*D	***CDS, 100y***

Urb – Urbanization, CC – Climate change, CSA – Cross-sectional area, RP – Return period.

Urban development - Urbanization



Left: current situation. 49% Impervious

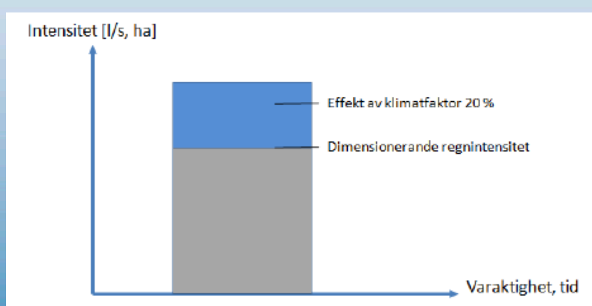
Right: Future development of the area. 80% Impervious

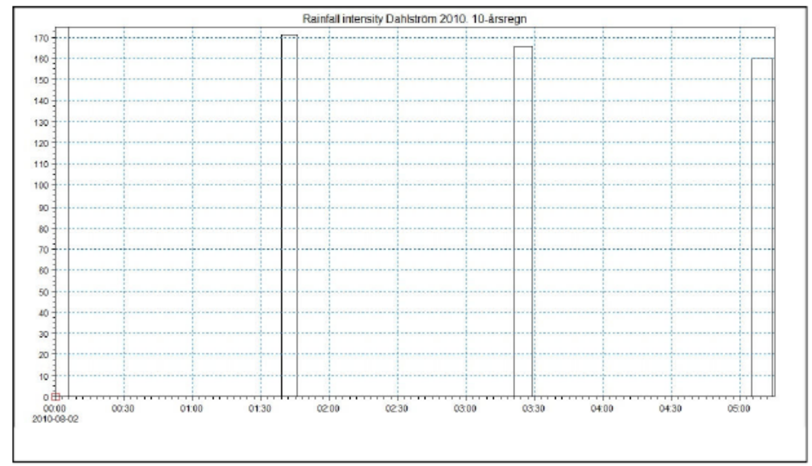
Rainfall statistics and climate change

Block rainfall
return period 10y, run in a sequence durations: 5, 6, 7, 8 min, with intensities: 113, 105, 98 and 92 mm/h (Baseline and Group 1 and 2)

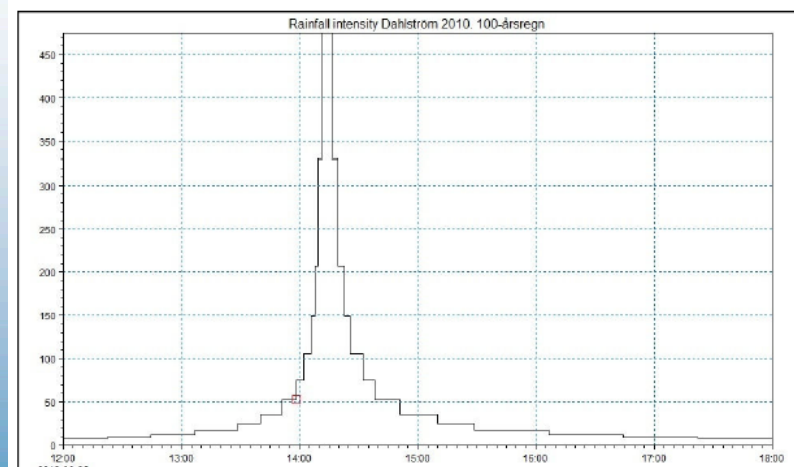
CDS rainfall
return period 100y, duration: 6 h (Group 3)

Climate factor: Constant uplift 20%





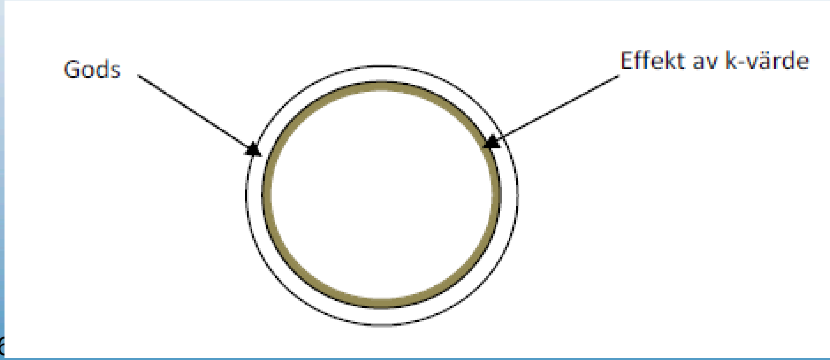
Figur 19. Blockregnsserie med varaktigheterna 5, 6, 7 och 8 minuter.

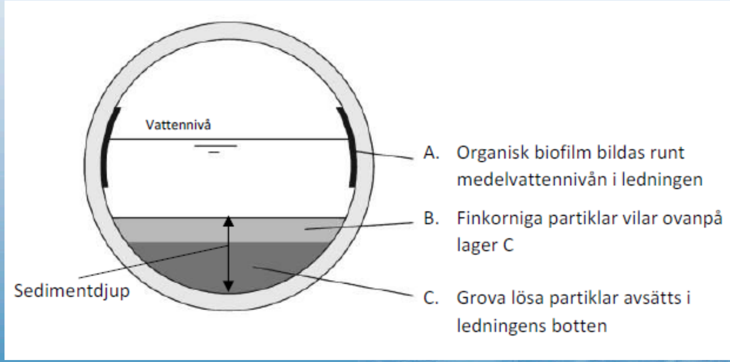


Figur 20. CDS-regn för kartläggning av vattenvägar ovan mark.

Pipe conditions

- Roughness of the pipe wall – equivalent sand roughness size (k)
  - k=3mm and k=6mm used in this study
- Decrease of available cross-sectional area, due to sediment deposits, biofilm accumulation, pipe system deterioration etc.
  - decrease of available cross-sectional area of 1/3rd





Small scale sensitivity analysis

Group	No	Urb [%]	CC [%]	Pipe k [mm]	Pipe CSA [-]	Rainfall, and RP
Baseline	0	-	-	3	-	Block, 10y
	1	***80***	-	3	-	Block, 10y
1	2	-	***20***	3	-	Block, 10y
	3	-	-	***6***	***1/3*D***	Block, 10y
	4	80	20	***3***	-	Block, 10y
2	5	80	20	***6***	-	Block, 10y
	6	80	20	6	***1/3*D***	Block, 10y
3	7	80	-	6	1/3*D	***CDS, 100y***

Urb – Urbanization, CC – Climate change, CSA – Cross-sectional area, RP – Return period.

Results

- Baseline scenario should correspond to a situation where the system is not flooded, according to national guidelines (SWWA, 2011).
- One reason for detected floods (17) is that the system was built using rainfall intensities based on earlier statistics which are lower than current statistics
- The differences are therefore of more relevance than the actual numbers.

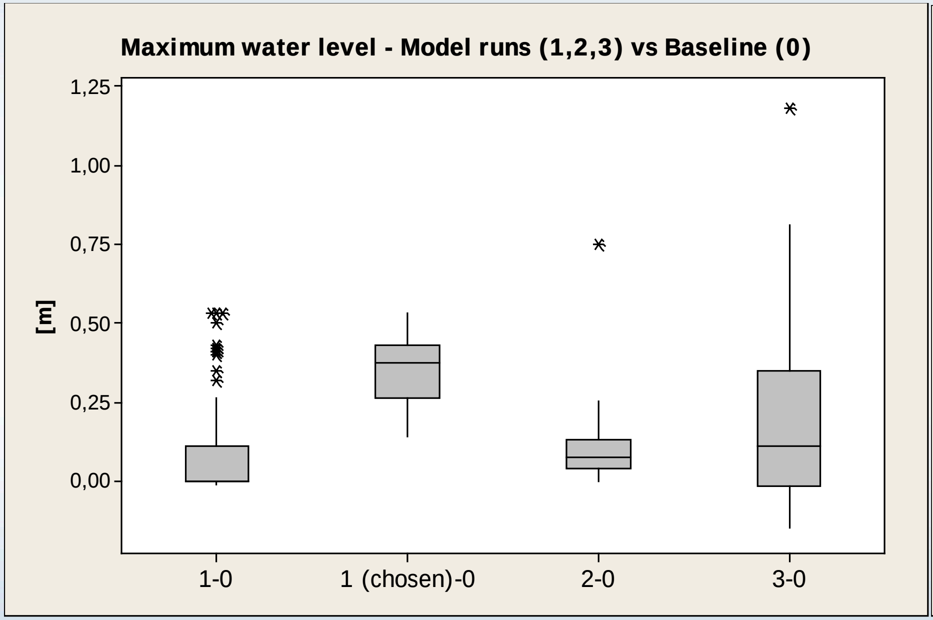
Affected nodes and pipes in the system

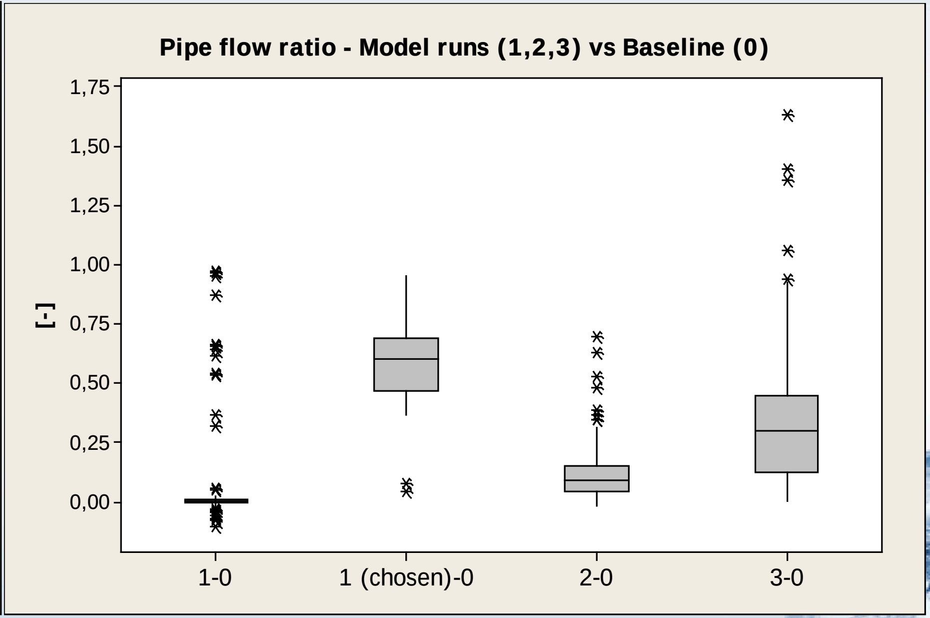
Group	No	Max water level in nodes ≥ GL	≥ CL	Max pipe flow ratio (Q/Q_{full}) <1	1-2	2-4	≥4
		(Number of nodes affected)		(Number of pipes affected)			
Baseline	0	17	30	45	10	10	5
1	1	18	39	46	13	7	4
	2	21	32	46	15	6	6
	3	22	33	35	19	8	8
2	4	21	63	39	17	8	6
	5	21	63	31	23	10	6
	6	26	68	23	28	12	7

Max water levels exceeding:

GL – Ground level, CL – “Critical” level (Pipe crown level)

Group 1:
Urbanization, Climate change and Pipe system deterioration





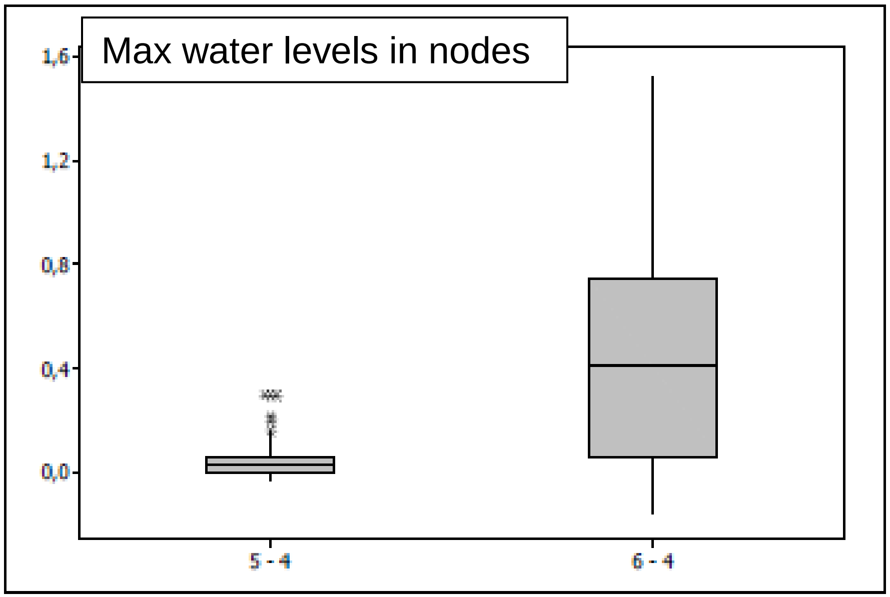
Differences between Baseline (0) and Urbanization (1), Climate change (2), and Pipe system deterioration, worst case (3).

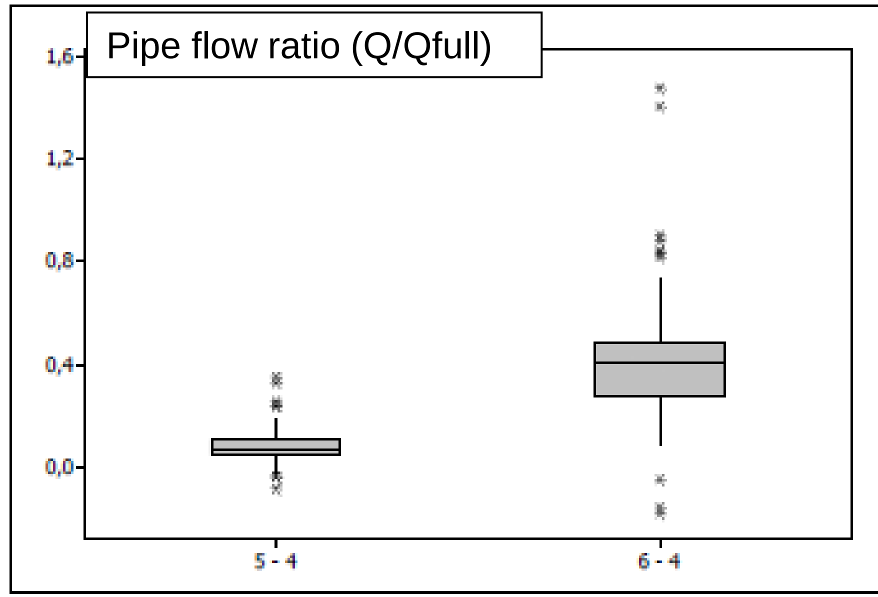
Chosen: only 18 of the total 72 nodes included

- All factors studied (climate change, urbanisation and pipe deterioration) have impact on the hydraulic capacity
- These aspects should be included in studies when evaluating the future situation
- Increased imperviousness may have a local impact on the hydraulic capacity, compared to climate change and the pipe conditions which impacts the whole area

Group 3:
Pipe system status

(constant urbanization and climate change)





Scenario 4: k=3mm - ”Baseline with Urb and CC”

Scenario 5: k=6mm

Scenario 6: k=6mm + CSA: 1/3*D

- Results from the study area suggest that deteriorating pipe condition is an important factor to consider when evaluating system capacity for the future.
- This can be evaluated using both the k-value (roughness coefficient) and a decreased cross-sectional area,
- however, more evidence is needed to assign realistic future values for these parameters.

LULEÅ UNIVERSITY OF TECHNOLOGY

Group 3:
Extreme event

- including suggestions for future urban development

Surface runoff routes, and flooded areas

Critical locations, e.g. flooded water running towards buildnings

Suggestions for future development of the area, including runoff directions