NTNU
Kunnskap for en bedre verden

Water and wastewater in 21. century

Challenges
Project- and master thesis 2019-20

Research group for water and wastewater



Courses 9. semester

- TVM 4141 Storm water/Asset management (Tone/Rita)

  Training in paper writing and presentation
- TVM 4510 Project work

  Training to plan, carry out and deliver results of a job within a given time deadline

  Preparation for master thesis, same or complete different topic (concentrate or widen out the ecperience).

Primarily link to ongoing project with post-doc or Ph D connected

- Drinking water treatment
- Treatment and recovery of resources from wastewater treatment
  - RECOVER, SIGERENS
- Industry (treatment of process liquids or treatment of wastewater
  - Siemens, Biokraft
- Storm water management
  - Klima 2050
- Resilient and sustainable rehabilitation of urban water networks
  - Ph D program in Norsk Vann

Drinking water treatment

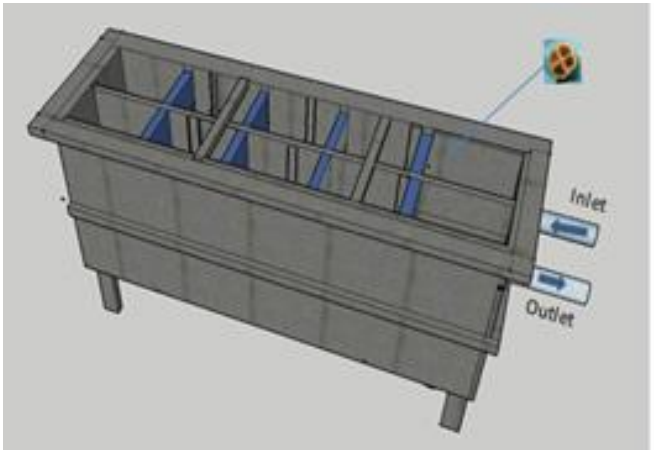
- Biostability of water in the distribution system – (partnership with post-doc Michael Waak)
- Biofiltration (with IVAR)

Contact person: Cynthia Halle mm.

Enhanced Biological Phosphorous Removal (EBPR) in flow through Moving Bed Biofilm Reactor (MBBR)

Projects: RECOVER

The enhanced biological phosphorus removal (EBPR) process is increasingly popular as a sustainable method for removal and subsequently recovery of phosphorus (P) from wastewater. The overall aim of this project is to carry out the EBPR in a flow through biofilm process utilizing a pilot-scale Moving Bed Biofilm Reactor (MBBR).



Task:

- Investigating the effect of wastewater quality and operational parameters on the process performance

Contact persons; Thomas Meyn, Blanca Silva, Stein Østerhus

Specific RECOVER tasks

- Biological phosphorous removal with aim of recovery
- The microbial community of environmental P removal in EBPR in continuous moving bed reactor
- Nutrient recovery from wastewater treatment
- Understanding nitrogen removal in an EBPR process based on MBBR
- Understanding the role of available carbon in EBPR process

Storm water management

Projects: KLIMA 2050

- Treatment of tunnel wash water
- Treatment of microplastics from road runoff
- Modelling concentration of de-ising chemicals at airport
- Thermal analysis of green/grey roofs in cold climate
- Detention and drainage capacity

Contact person: Thomas Meyn, Tone Muthanna

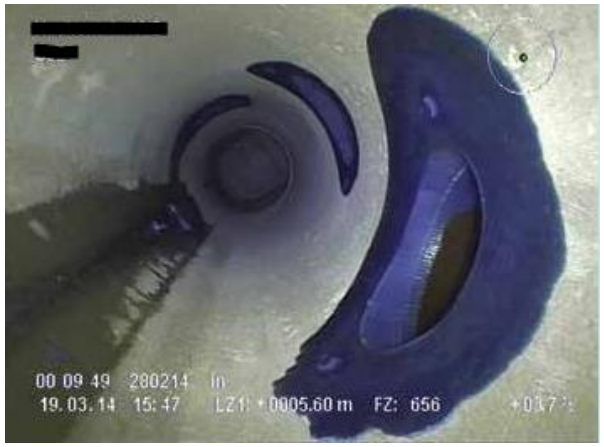
Klima 2050

Impact of climate change on built environment

BINGO

Asset management

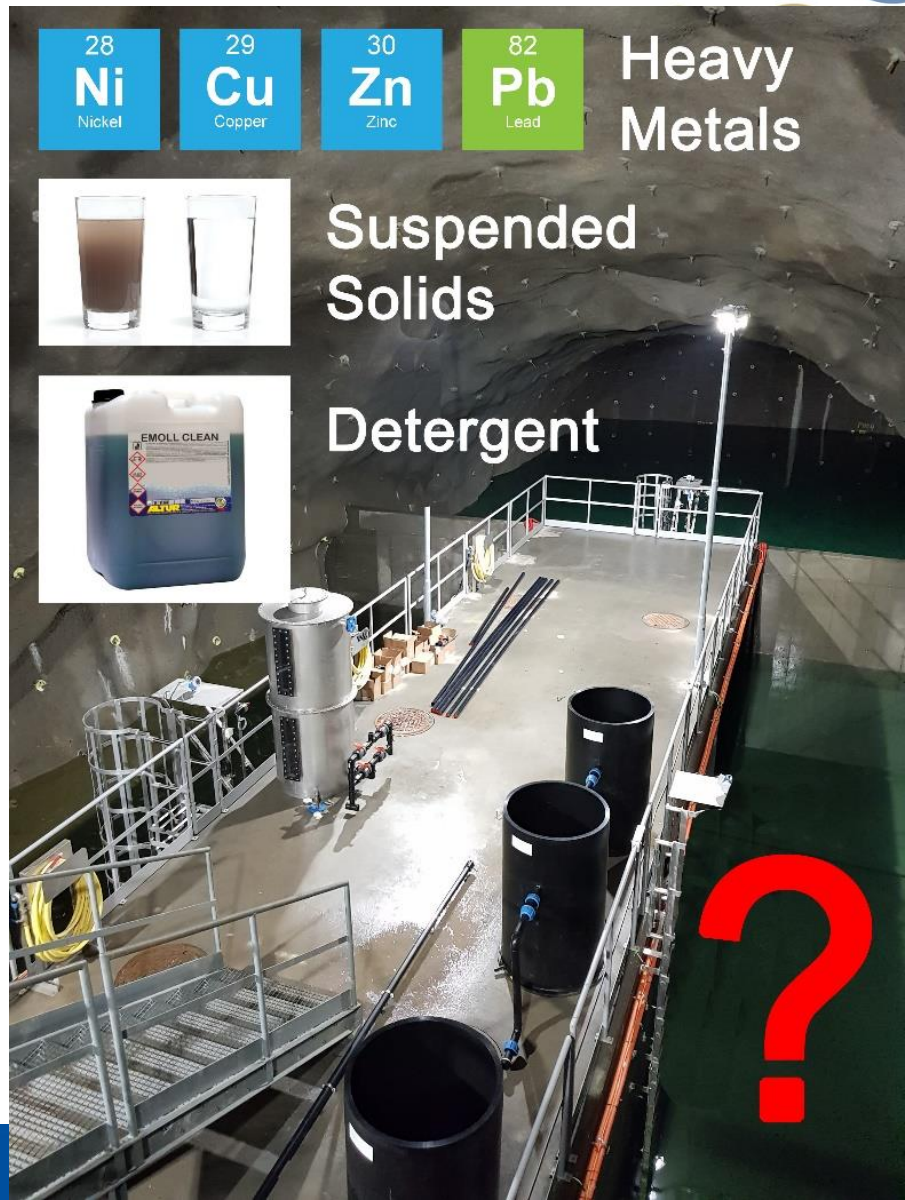
- Influence of data quality and measurement location on hydrodynamic sewer model calibration
- Decision support for sewer rehabilitation techniques
- Influence of sewer condition assessment on deterioration models



Contact person: Franz Tscheikner-Gratl

Management of tunnel wash water

- Mye høyere forurensing en i avrenning fra vei (i Norge)
- Forurensninger i partikulært eller løst form
  - Metaller, organiske stoffer, mikroplast
- Bruk av såpe
  - Giftig
  - Mobiliserer
- Sedimentering har blitt standard, men fjerning av oppløste stoffer blir krav



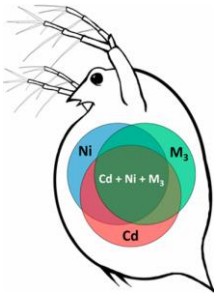
Statens vegvesen

Toxicity of tunnel wash water

- Kan være svært giftig, men hvor kommer det fra?
  - Metaller, organiske stoffer, såpe?
  - Endres det over tid?
  - Hva slags effekt har sedimentering?

Norsk institutt for vannforskning

Statens vegvesen



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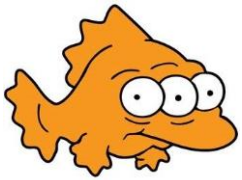
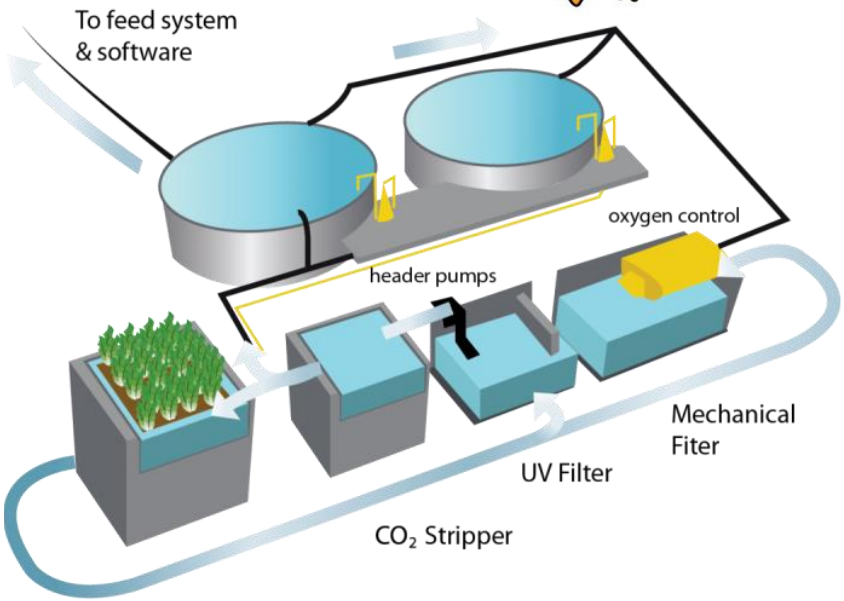
Water quality in recycling aquaculture systems (RAS)

- RAS is an “environmental friendly” farming option
- Reuse of water leads to concentration of particles, nutrients etc.
  → Water Treatment Needed
- Little knowledge about presence of particles in the system
  - Source?
  - Composition?
  - Removed by treatment?





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Stormwater Management – some suggested topics for research

Associate Prof. Tone M. Muthanna

Stormwater management in 2020

Water balance – urban spaces – pollution control – infrastructure management

Sustainable stormwater management – Water balance and infiltration and evapotranspiration – urban streams – flood co… f… re… liv… u… gre… bl… ur… to… ch… nc… gn… wa… he… se… in… mv… an… solutions

KLIMA2050

Some Suggested Master thesis topics in collaboration with Klima2050 and the partners

Other options possible as well, so just get in touch with us if you want to discuss one of these or other options.

Stormwater: Measurement techniques – understanding infiltration based systems

Trondheim kommune oppgraderer Trondheim torg og tilstøtende gater. I den forbindelse blir det etablert et nytt anlegg for overvannshåndtering som skal avlaste dagens ledningsnett i Midtbyen. Anlegget vil bestå av et infiltrasjonssystem og et fordrøyningsmagasin og bli konstruert slik at fordrøyningsmagasinet kun benyttes når infiltrasjonssystemet har nådd sin maksimale kapasitet. Anlegget er designet og dimensjonert av Multiconsult.

Vi ønsker å undersøke:

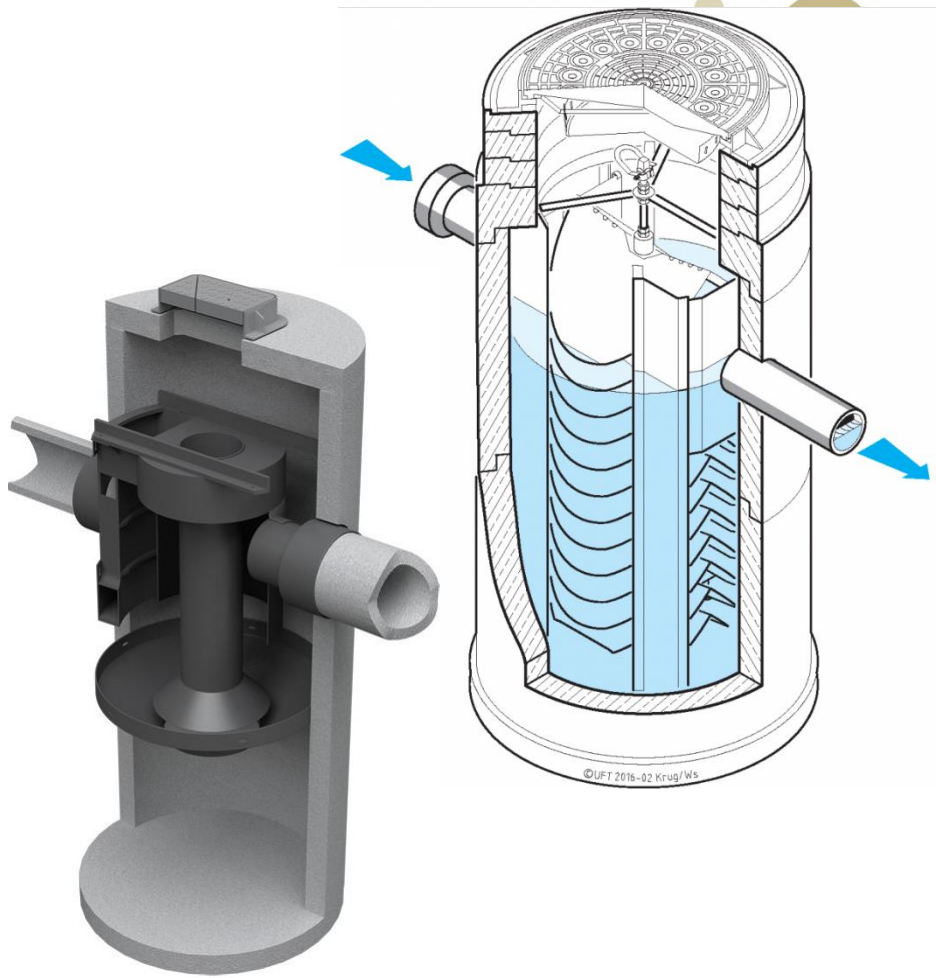
- Hvordan dette systemet fungere over tid, kapasitet og frekvens på aktivering av overløp til fordrøyningssystem
- Prøve ut areal-hastighetsmålinger (dopler og trykk) over tid på et online overvannssystem.
- Vurdere hvordan infiltrasjonsystemer kan redusere krav til fordrøyninsvolumn – praktisk dimensjonerende.
- Bygge en sytem model for prosjektering som kan verifiseres med data fra anlegget

Keywords: System modelling (MatLab, Phyton, R), infiltration based systems, flow monitoring

Advisors: Tone M. Muthanna, Gema R. Raspati og Edvard Sivertsen

Stormwater: Supersandfang – performance in Nordic climates

Trondheim kommune har installert et så kalt «supersandfang» - kum med innebygd renseløsning på en forurensningsbelastet veistrekning på Heimdal. VI ønsker å se på hvordan disse fungere i et kaldt kystklima, men hyppig nedbør med relativt lav intensitet.



Vi ønsker å undersøke:

- Dokumentere rensegrad over flere hendelser over tid (feltmålinger og installer prøvetakere), helst kombineres med prosjektoppgave.
- Lage en modell som kan beregne rensegraden i ulike klimasoner.
- Vurdere kost/nytte/area bruk opp mot alternative mer plasskrevende løsninger som regnbed og infiltrasjonsgrøfter.

Keywords: Systemmodellering, kompakte renseløsninger, feltmålinger

Advisors: Tone M. Muthanna, Birgitte G. Johannessen (Trondheim Kommune), Lisa Hoven (Multiconsult)

Stormwater: Urban street and roads as floodways

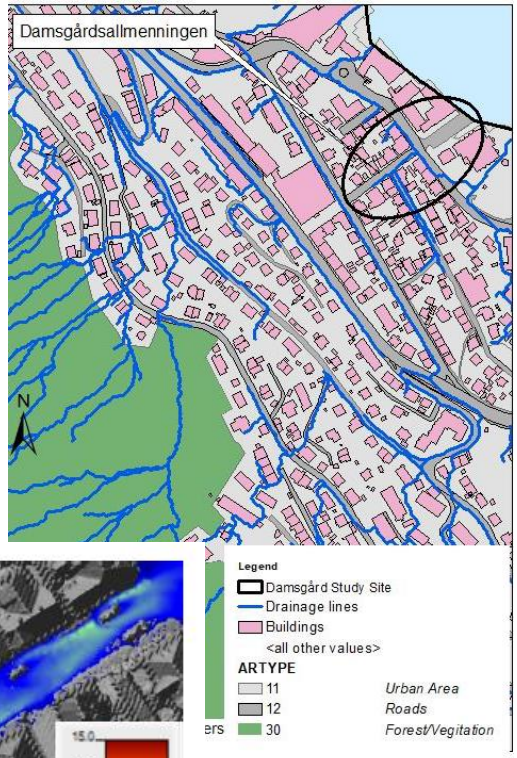
I 3-trinnsstrategien er sikkerflomvei trinn 3. Dette er krevende å etablere i eksisterende bybebyggelse. Flere byer i Norge ser på bruken av veier og gater som flomveier. Vi har begynte p jobbe med Bergen kommune med dette i fjor og ønsker å ta denne modelleringen videre.

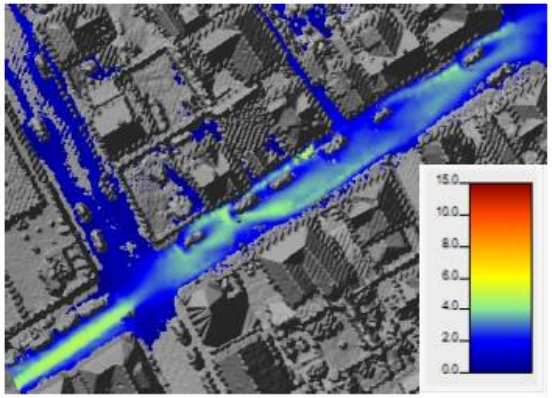
<u>Vi ønsker å undersøke:</u>

- Videreutvikle konseptet om tverrgående flomveier, mot langsgående (i fallretningen)
- Utvikle optimale tverrsnitt for gater som blir brukt som flomveier, som tar høyde for både;
  - Transport kapasitet
  - Hastighet
  - Sikkerhet
- Forslag til dimensjoneringskriterier

<u>Keywords</u>: HecRas, Flood modeling, Urban floods, Optimal design criteria

<u>Advisors</u>: Tone M. Muthanna og Knut Alfredsen





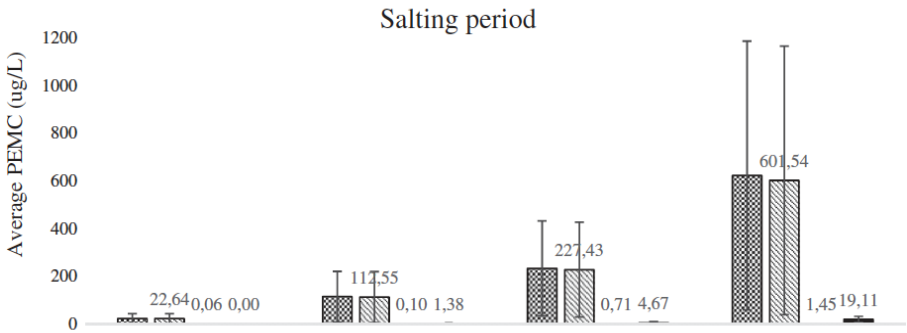
Maximum velocity distribution $[^{m}/_{s}]$ in the street with runoff from watershed A for a 60

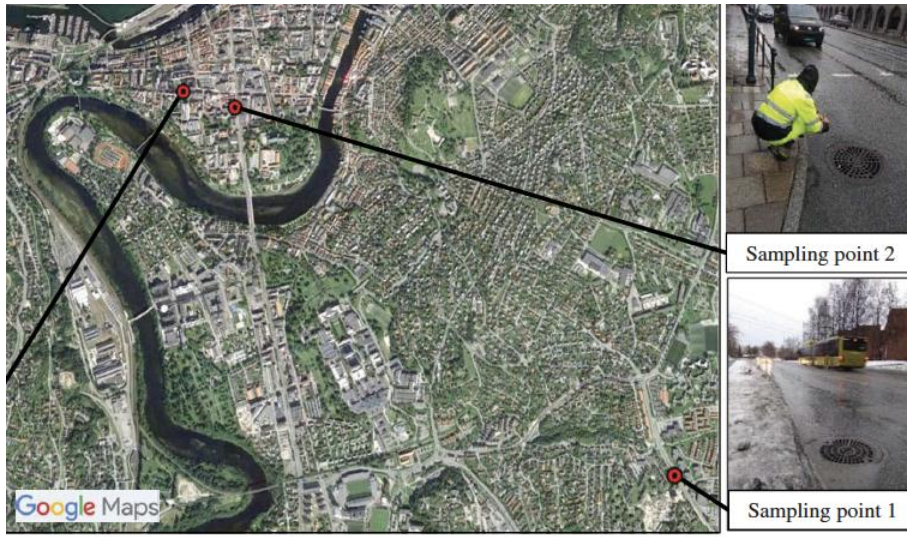
Stormwater: Pollutant characterization and transport pathways

Pollutants are caracterized as particulate bound or dissolved, which greatly influences their transport pathways. Exploring the pollutants association to different particle sizes we can target the treatment measures and greatly imporve the treatment efficincy.

Objectives:

- Build on previous work to further understand the particulate /dissolved fractions and how road salt applications influence this.
- Build a model based on observed /field data to predict the treatment efficieny in various stormwater treatment systems i.e rain gardens or sedimentation based systems.
- Investigate how urban activities change the particle size distribution and pollutant association.





<u>Keywords</u>: Particle size characterization, pollutant pathways, truly dissolved pollutants

<u>Advisors</u>: Tone M. Muthanna, and Thomas Meyn and a collaboration with Luleå Tekniske Universitet

Water and Wastewater Infrastructure – some indicative topics for research

Prof. Christos Makropoulos

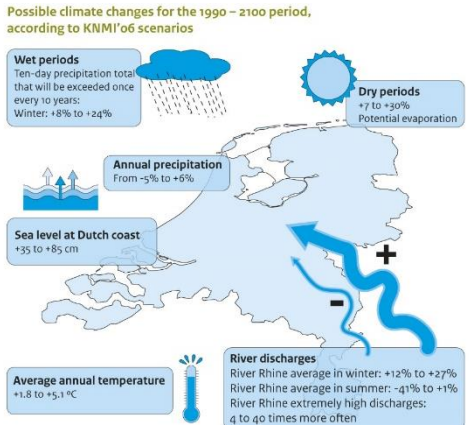
First: some context

Infrastructure planning is a challenge of multiple aspirations

Connecting demand and supply? Reducing water losses? Managing demand? Ensuring coverage? Protecting the environment from pollution? Climate proofing cities (for too much or too little water)? Supporting citizen well being? Supporting industry (climate and market proofing it)?

These aspirations need to be achieved within a shifting landscape – in more ways than one.

Climate is changing a lot and faster than we would have liked



Supply patterns are affected (both in terms of quantity and quality)

Demographics are shifting through (also) due to geopolitical reasons

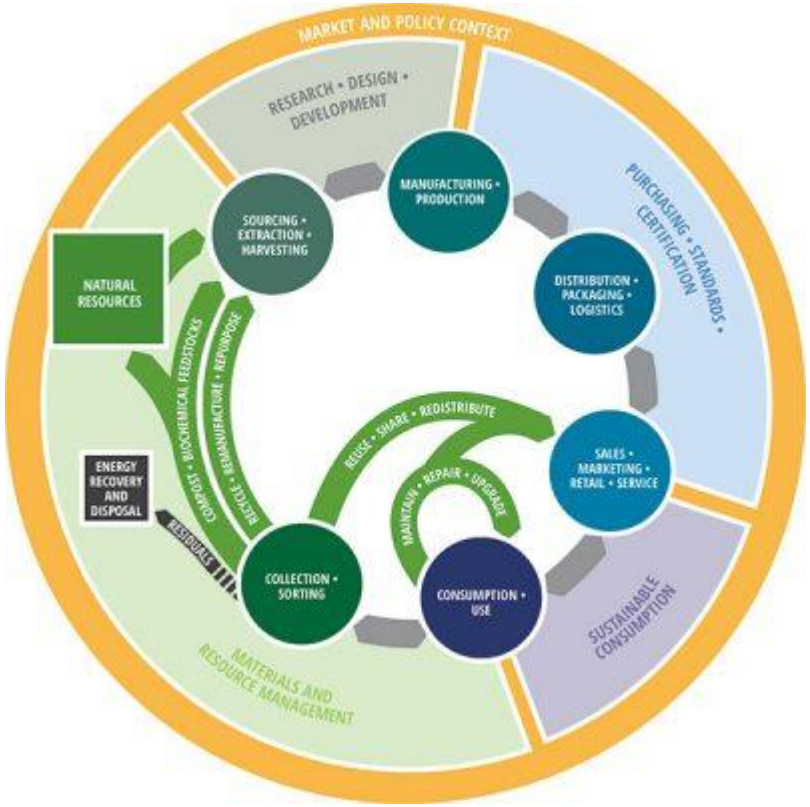
Demand patterns that used to change slowly are now changing faster – also affected by geopolitical shifts

The economy is still in too much flux, affecting investment for assets replacement

The sector lags behind in **investment** needed for infrastructure – and is affected more and more by related sectors (e.g. energy)

This shifting landscape prompts research and practice to look into new ways of thinking about water infrastructures

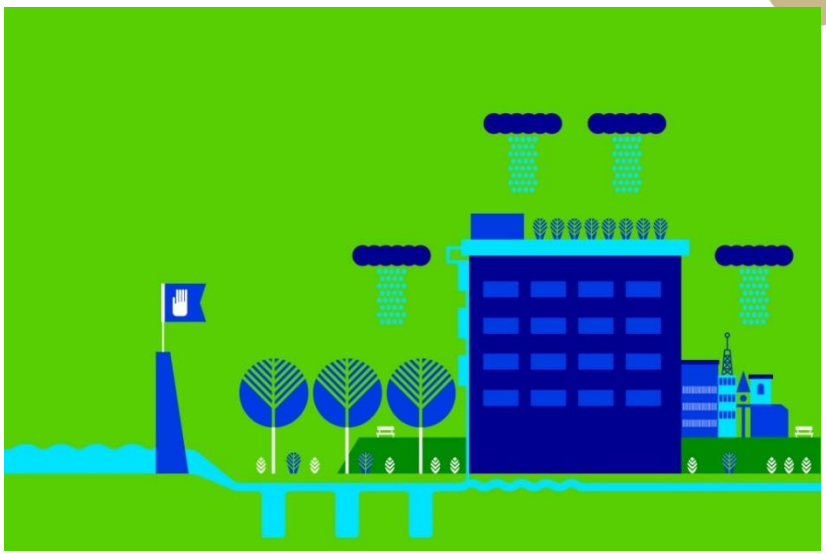
- **Aging infrastructure** is both a problem and an opportunity: it reduces the **'lock-in'** that comes with large scale centralised infrastructure and opens up possibilities.
- The **uncertainty** that comes from the sifting landscape prompts new thinking around **autonomy**, **resilience**, **interconnectedness** and **security**.
- This also suggests new governance and market **configurations** that can support such concepts – namely the idea of the **circular economy.**



Re-thinking what water infrastructure is and what it does…

Can our infrastructure be:

- **smarter** (exploiting ICT),
- more **efficient:** reduce water and energy demands by being more **proactive** (reductions of leakage/bursts and peak water consumption, RTC),
- more **integrated and cyclical:**
  - Blue + Green infrastructure,
  - Water + Energy (Renewables!)
  - Water + Digital
  - Waste(water) to Resource (Reuse, Harvesting, CE)
- To be more **resilient.**

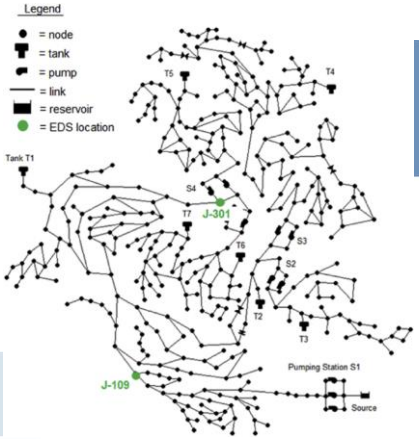


Water, green, energy, transport and ICT infrastructure need to be better **integrated** and **benefit** from each other.

A word of caution: there are flip sides to all these nice words: think cyber vulnerability, efficiency vs resilience, intrusiveness, cascading effects, health hazards

So, what are (some indicative) thesis topics we could research together within this context?

What is resilience in Urban Water Systems? A comparative exploration of metrics and methods for water infrastructure design



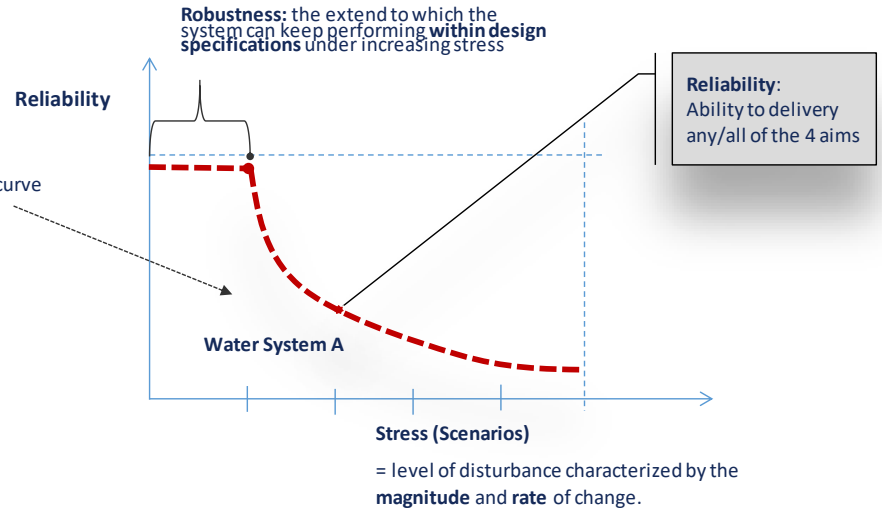
- A lot of definitions of resilience have emerged lately!
- There are no real wrongs and rights here – each definition serves a purpose and highlights a different aspect of the performance of an urban water system under uncertainity.
- In this work we will investigate these **different definitions**, apply them **in the same case** and **compare** what we (and water companies) can learn from them.
- We will also develop **guidelines** and **meta-metrics** for their combined exploitation.
- We will also attempt to use resilience 'maximisation' as an objective funtion for WDS design (never tried before!)
- **Keywords**: Water System modelling, UWOT, MATLAB

Degree of continued performance: is measured through **reliability**

Degree of **continued performance** of the **system** under **disturbance**

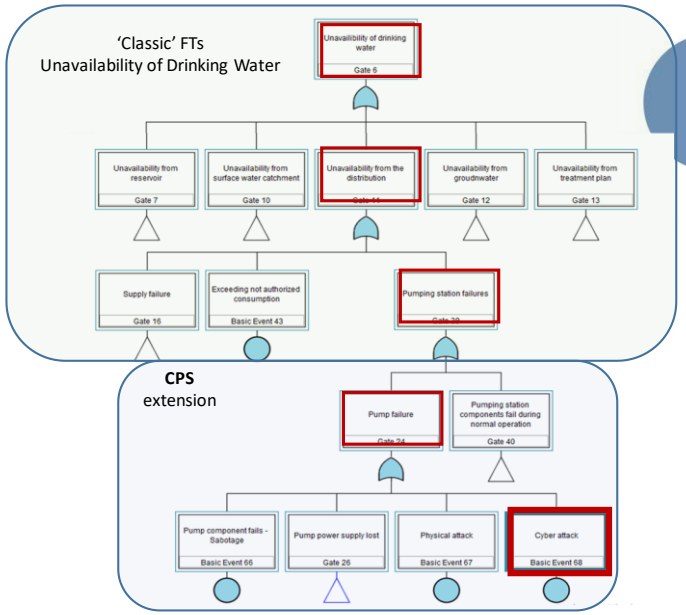
The water **system** is influenced by both what is installed (**technologies**) and how technologies are connected (**design**)

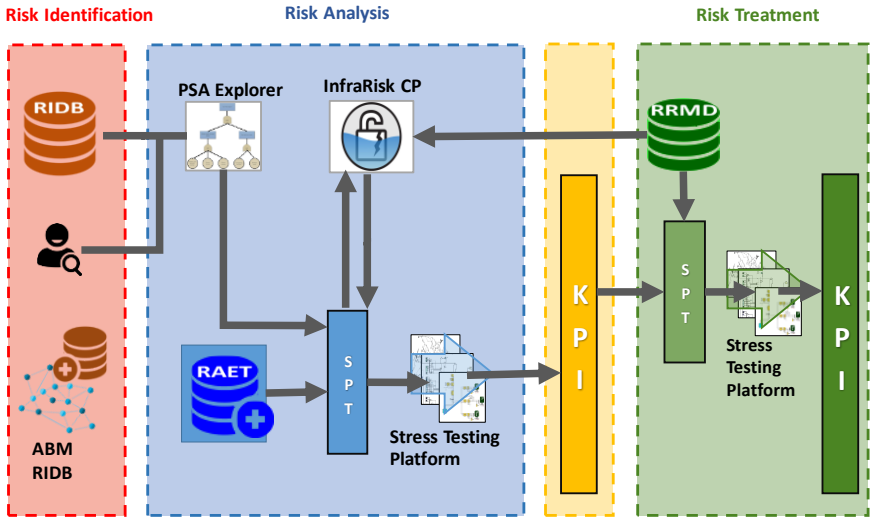
Disturbance can be modelled through sensitivity, projections, **scenarios** (from word views to black swans)



Risk Assessment for Cyberphysical Water Distribution Networks: a scenario ensemble approach

- UWS are **no longer just physical** infrastructure with some sensors!
- Driven by **efficiency and security** we have sensed-up our systems and **now they are vulnerable to new attacks** – up to now reserved only for Banks!
- Here we will use simulation tools developed in an ongoing research project (STOPIT) to assess the way a water distribution system performs against a large number of threats!
- **Multi-scenario risk analysis** will be used to trigger unexplored operational or design weaknesses, and identify which event or event-combination and under which conditions pose the most serious threat for the infrastructure.
- We will also develop a metric of overall risk of a WDN against 'cyber-physical' attacks (rather than one specific attack).
- **Keywords**: Water distribution network modelling; EPANET, MATLAB





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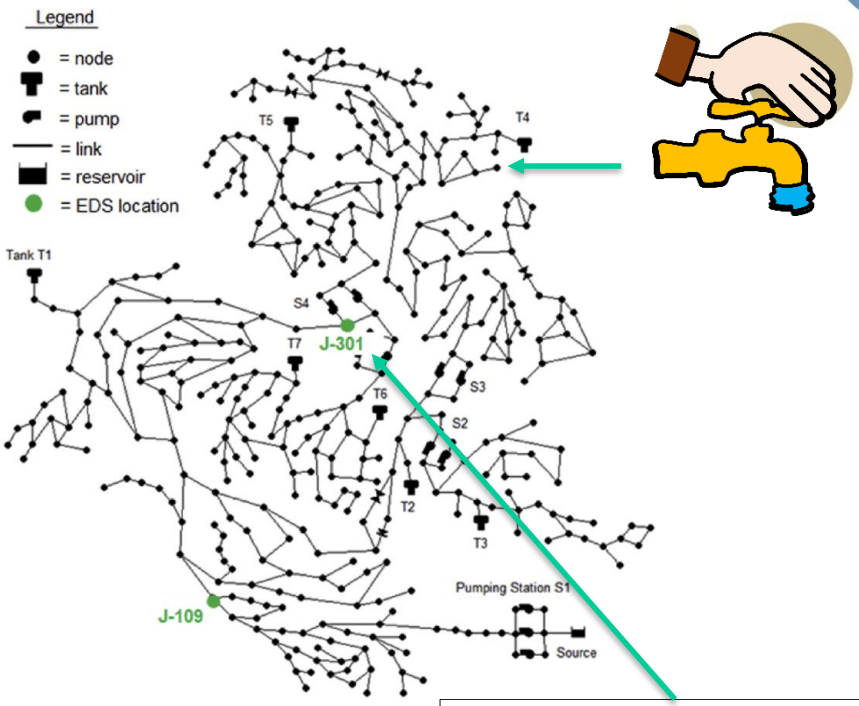
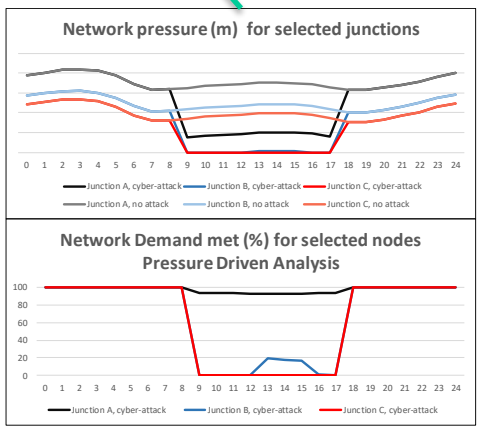
Developing Response Strategies for Cyberphysical Water Distribution Networks

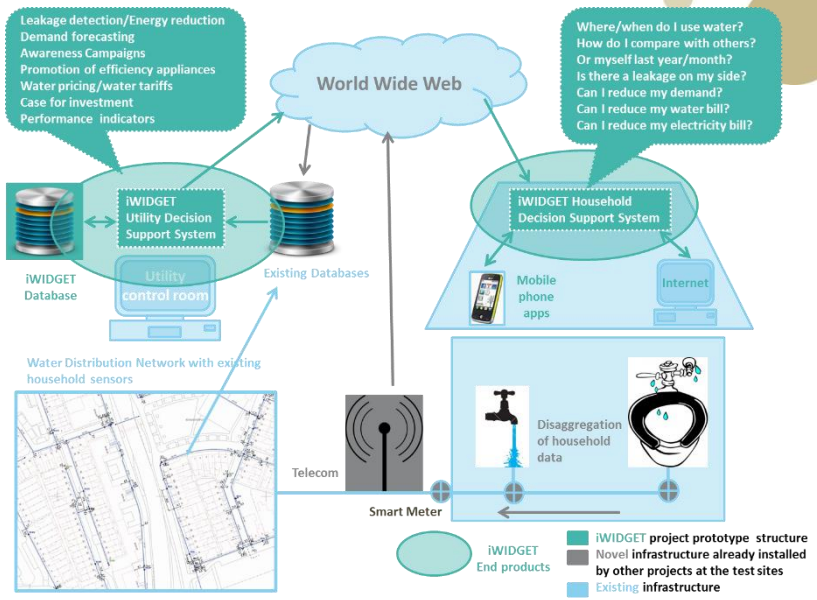
- When **something goes wrong in a network** (accident or incident) we usually model effects as if nobody reacts to what is happening.
- **But this is not true:** when a contamination enters the WDN (and is detected) the water companies issue alerts and customers close their taps. When pressure drops, people don't take baths. Companies themselves also react by closing off parts of the network.
- Here we will investigate these '**response strategies**' and identify appropriate ones - both water company implemented and customer –driven. We then develop approaches to model them for WDNs. Finally, we use the modified modelling strategy to see what is a **realistic** performance of WDNs under attack.
- **Keywords**: Water distribution network modelling; EPANET, MATLAB

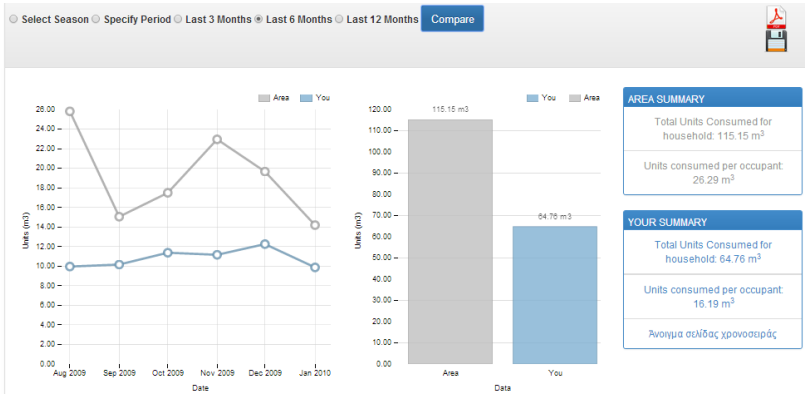




Developing a smart water meters deployment strategy: how many are ‘enough’?

- Smart meters, smart sensing, smart analytics are becoming a key ingedient of **smart water management**.
- Having high resolution smart meters is very useful as a source for information for both customers and water companies (to better design and control their networks).
- But high resolution smart meters are very expensive and their batteries don’t last.
- **How many of these are really necessary** combined perhaps with cheaper, lower resolution meters.
- Using a new method we will attempt to **answer this question for a typical Norwegean city** (Trondheim?).
- To prove our solution we will use the suggested deployment and compare modelling results based on that, to ‘real’ results where complete information is assumed.
- **Keywords**: Data analytics, water distribution networks, MATLAB





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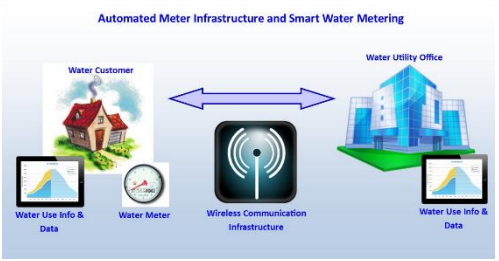
But of course other variations on these themes can be explored. Thesis topics are driven by your curiosity…

Water distribution modelling – estimation of water consumption and leakages based on smart water meter data

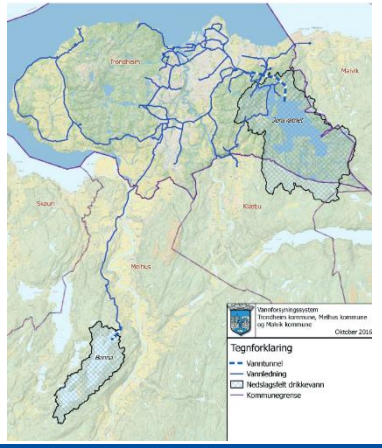
Trondheim kommune has ambitions to **reduce the leakages** in their WDS from 28 to 20 %. In order to achieve this goal, **considerable investments** must be made, with regards to pipe rehabilitation, pressure management and leakage detection. However, it is also of paramount importance to have **good estimates of the current water consumption, leakage level** and minimum night flow in the system.

Trondheim has currently approximately 35 DMAs, but there is currently an ongoing project to **increase the number of DMAs**. Trondheim is also involved in a project where **smart water meters (SWMs)** are being tested. It is assumed that these developments will make it **possible to obtain better estimates** on the water consumption and loss. The use of advanced **statistical analyses and artificial intelligence** may also help make sense of such data.



A master thesis with the following tasks and objectives is therefore suggested:

- Perform literature study on smart water meters, leakages, estimation of consumption and leakages
- Collect data from Trondheim's SWMs and SCADA system
- Perform statistical analyses on collected data to get estimates of:
  - Minimal night consumption and leakage level
  - Water consumption, with variations in time and space
- Evaluation of results and assessment of the usefulness and potential for installing SWMs in Trondheim



Keywords: Smart water meters, leakage management, statistical analysis

Advisors: Marius M. Rokstad, Sveinung Sægrov. Possible collaboration with TU Berlin?

TVM4130 - Urban water systems

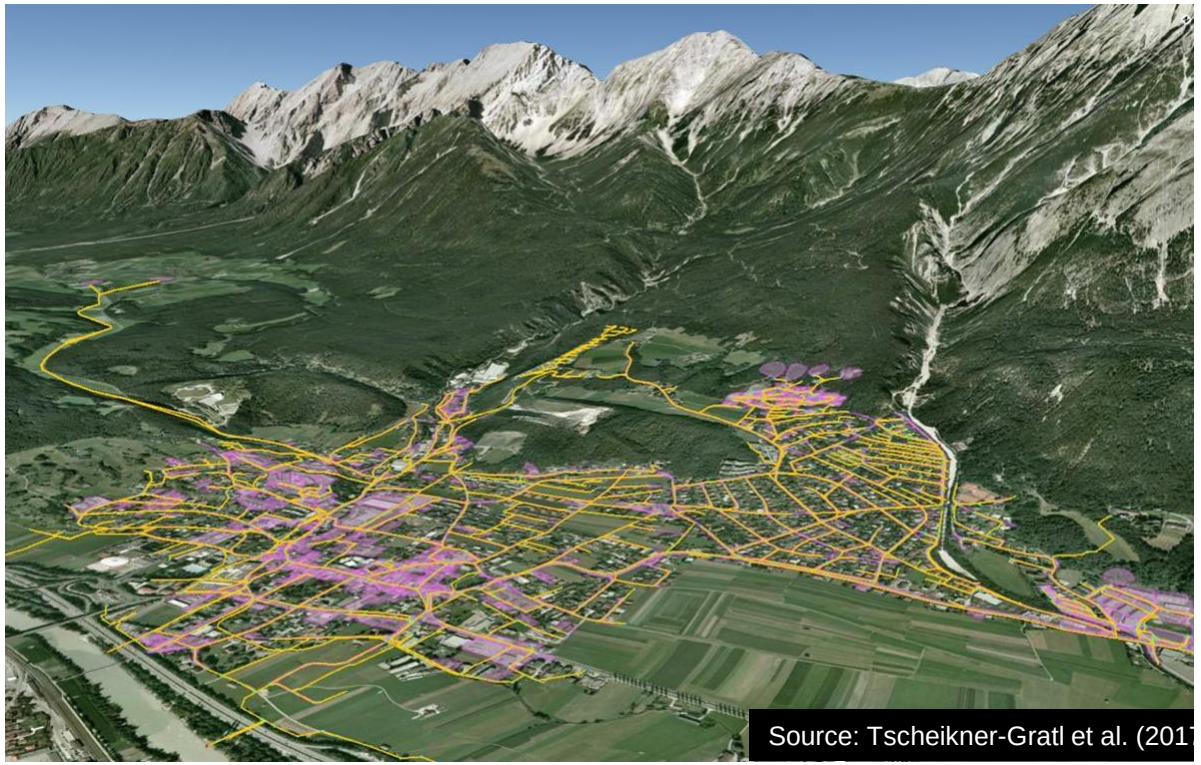
Focus: Sewer asset management

Contact person: Franz Tscheikner-Gratl

Norwegian University of Science and Technology

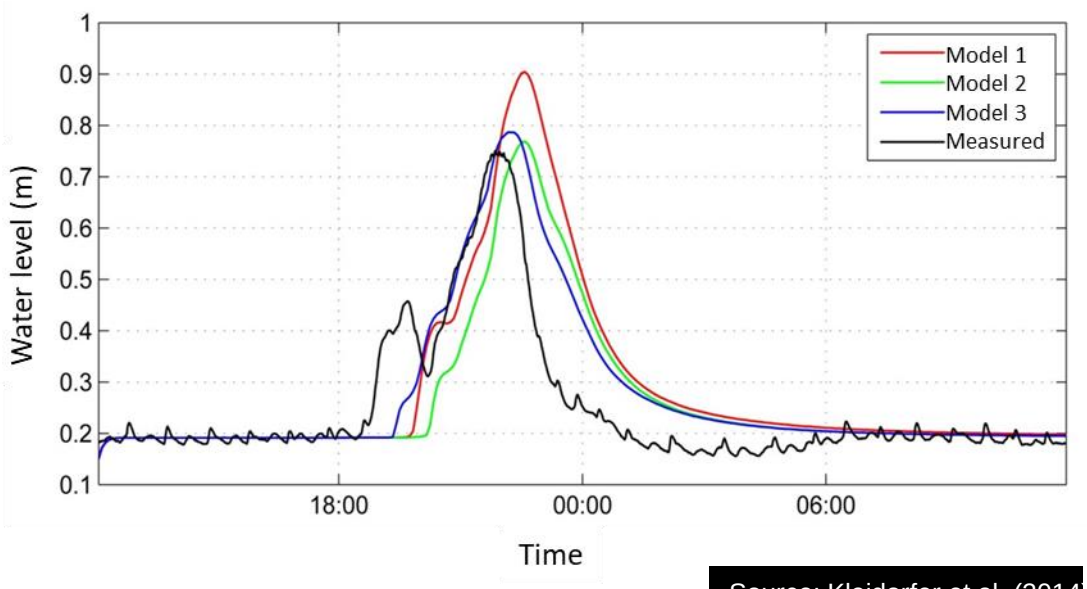
Possible Topics

- Influence of data quality and measurement location on hydrodynamic sewer model calibration
  - Hydrodynamic sewer models are an important planning tool



Possible Topics

- Influence of data quality and measurement location on hydrodynamic sewer model calibration
  - Hydrodynamic sewer models are an important planning tool
  - Hydrodynamic models need to be calibrated and validated with proper data to work properly



Source: Kleidorfer et al. (2014)

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Possible Topics

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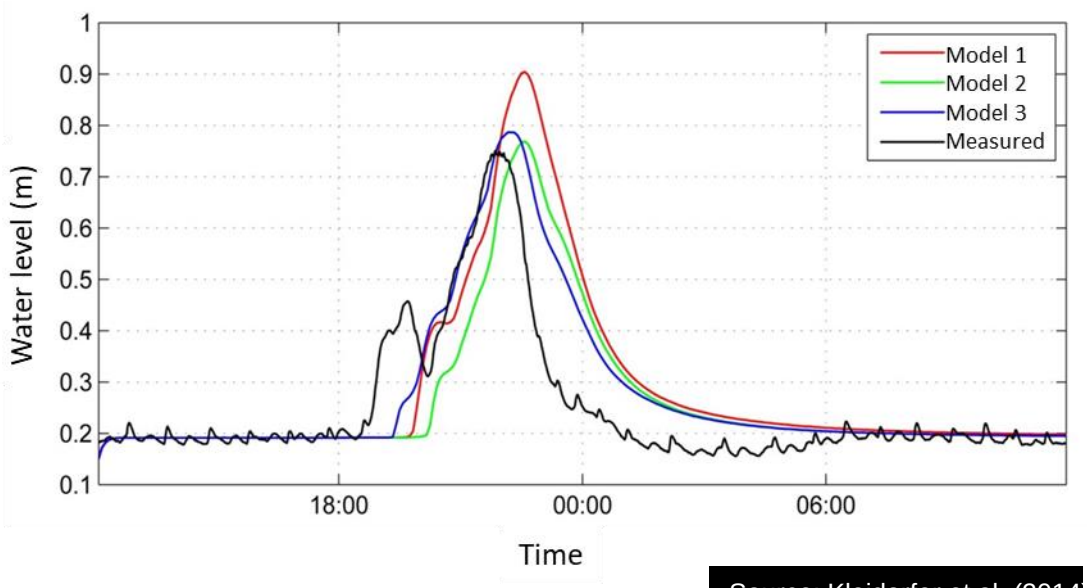

Source: Kleidorfer et al. (2014)

Possible Topics

- Influence of data quality and measurement location on hydrodynamic sewer model calibration
  - Question: What is proper data and what can be done if we don’t have it?

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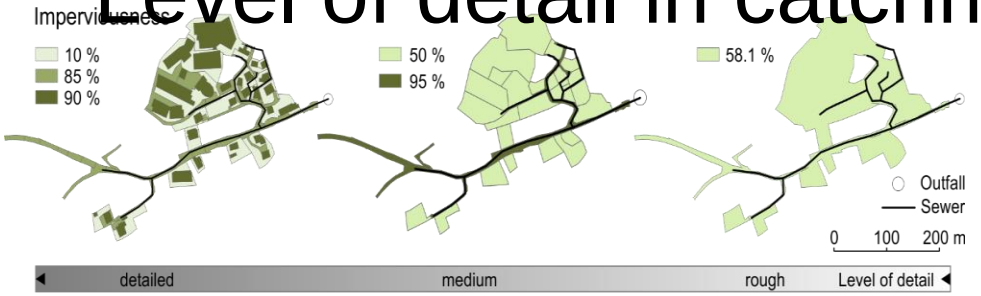
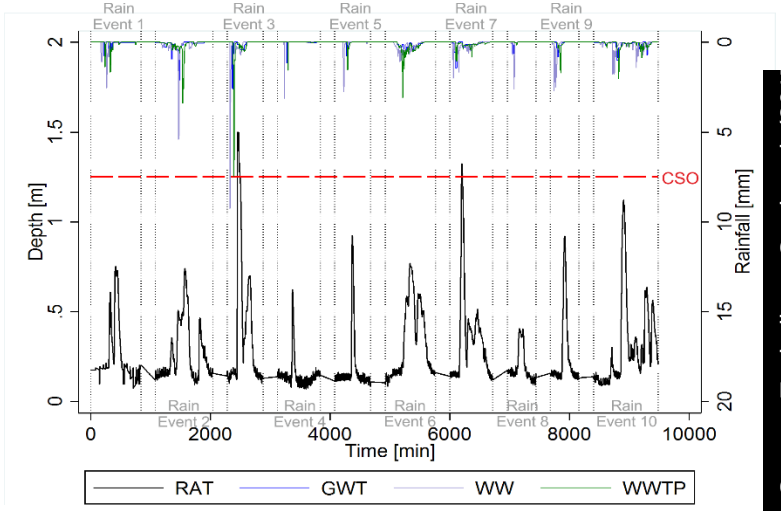
Level of detail in catchment assessment





Temporal resolution of measurement data
Measuring of water level, flow, binary data
Length and number of rain events used

Source: Tscheikner-Gratl et al. (201

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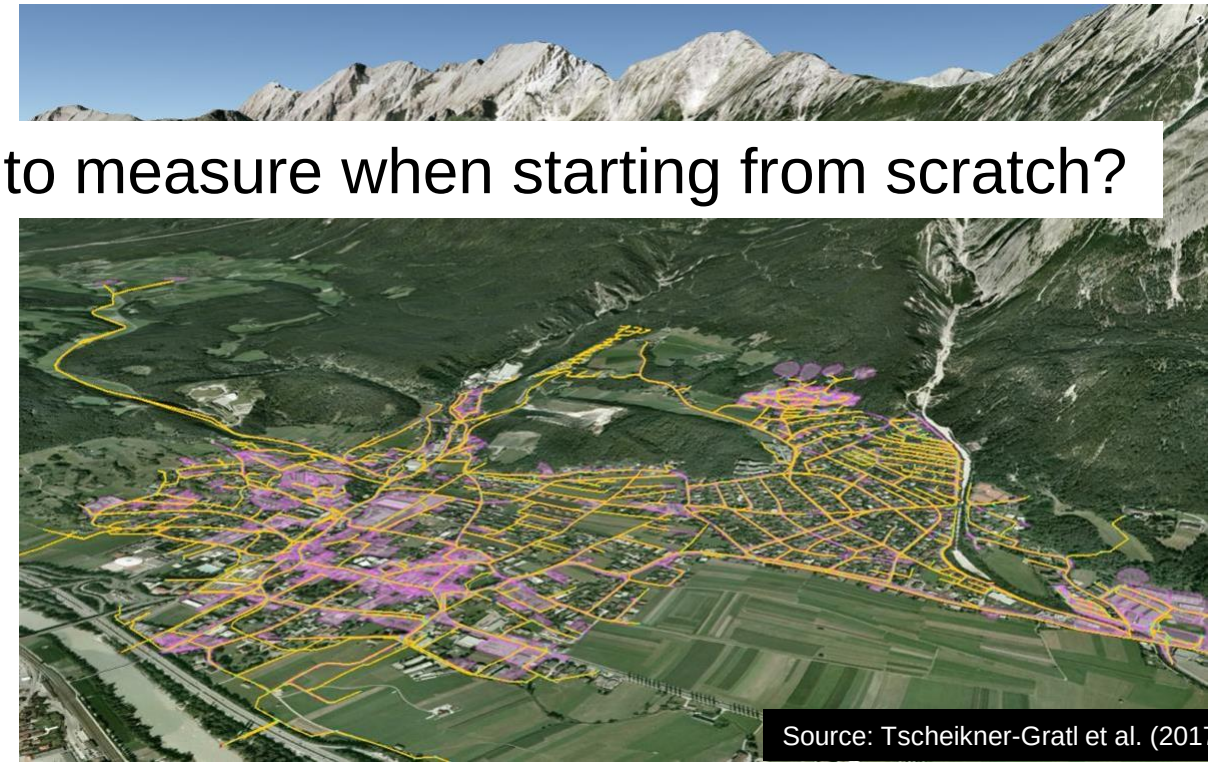
Possible Topics

- Influence of data quality and measurement location on hydrodynamic sewer model calibration
  - Question: What is proper data and what can be done if we don't have it?

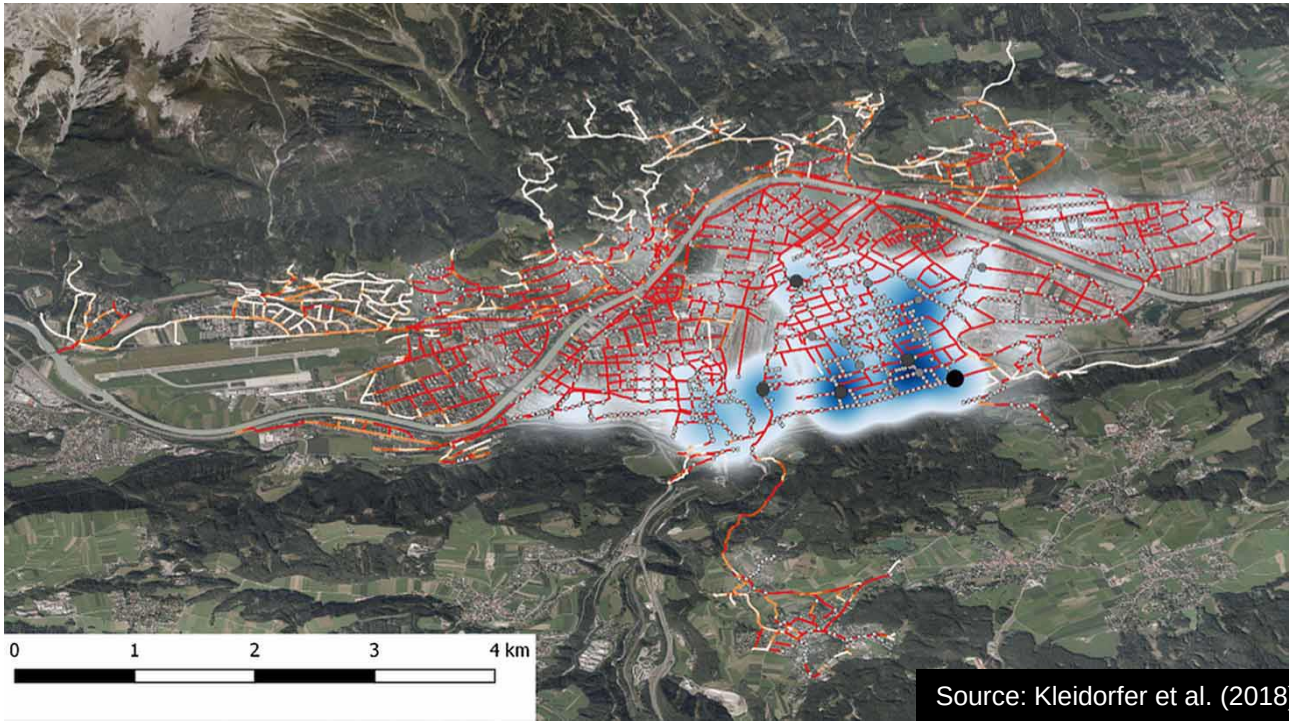


Where and what to measure when starting from scratch?

Source: Tscheikner-Gratl et al. (201

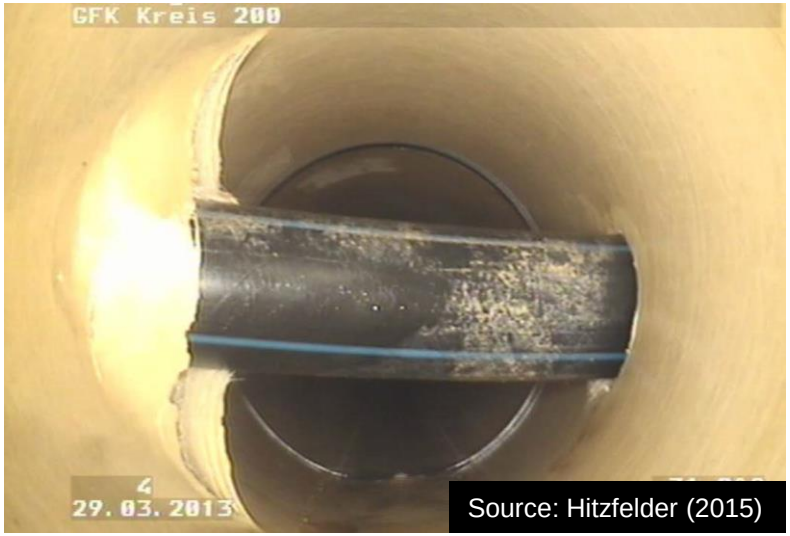
Possible Topics

- Influence of data quality and measurement location on hydrodynamic sewer model calibration
  - Question: What is the influence of the data selection on the model performance

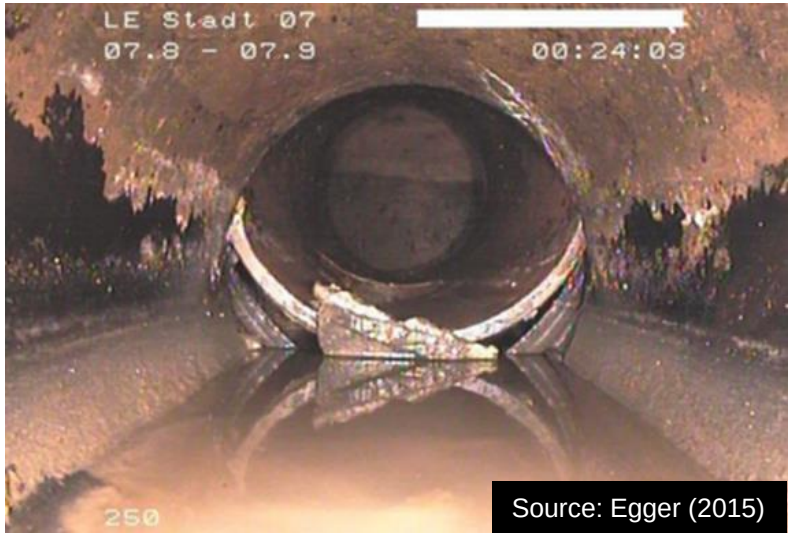


Possible Topics

- Decision support for sewer rehabilitation techniques
  - Sewer deteriorate over time



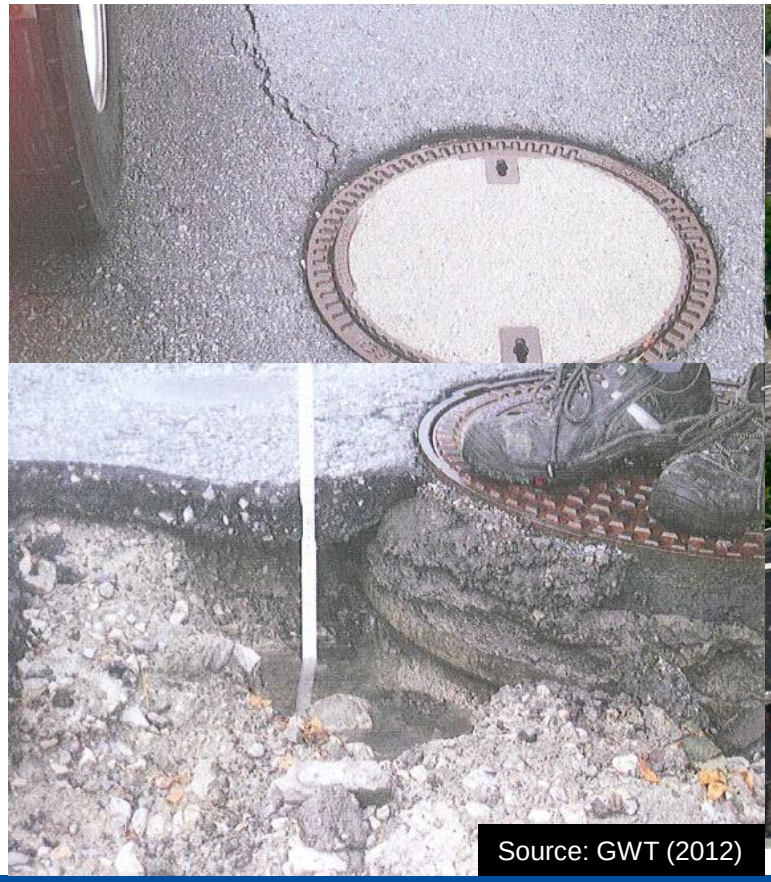
Source: Hitzfelder (2015)



Source: Egger (2015)

Possible Topics

- Decision support for sewer rehabilitation techniques
  - Consequences of this deterioration differ



Source: GWT (2012)

Source: National Geographic (2010)

Possible Topics

- Decision support for sewer rehabilitation techniques
  - Lot of different techniques for sewer rehabilitation

Possible Topics

- Decision support for sewer rehabilitation techniques
  - Question: Which technique to use when?

Possible Topics

- Decision support for sewer rehabilitation techniques
  - Question: Which technique to use when?
  - Answer: Until now often decided by experience, expert intuition or comparison of costs between limited alternatives

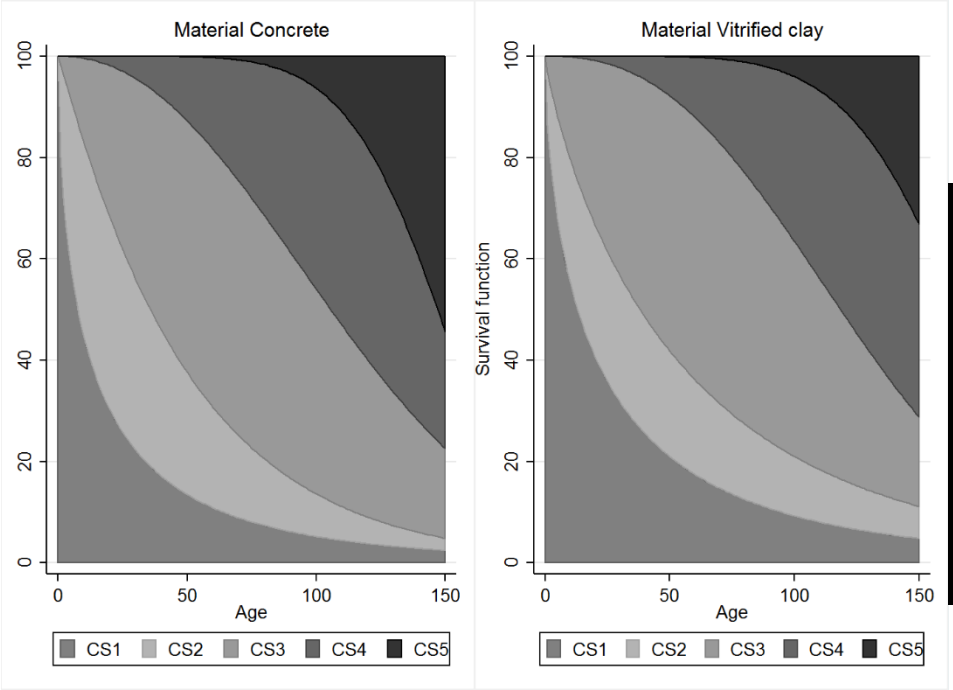
Possible Topics

- Decision support for sewer rehabilitation techniques
  - Question: Which technique to use when?
  - Answer: Until now often decided by experience, expert intuition or comparison of costs between limited alternatives
  - Task: Finding a Multi-criteria decision analysis tool to help the decision makers

Source: Margerison-McCann (2015)

Possible Topics

- Influence of sewer condition assessment on deterioration models
  - Deterioration models are useful tools to identify pipes in critical condition and long-term investment planning.



Source: Tscheikner-Gratl (2015)

Possible Topics

- Influence of sewer condition assessment on deterioration models
  - Deterioration models are useful tools to identify pipes in critical condition and long-term investment planning.
  - For sewer systems they are based on Condition assessments mostly made using CCTV inspection

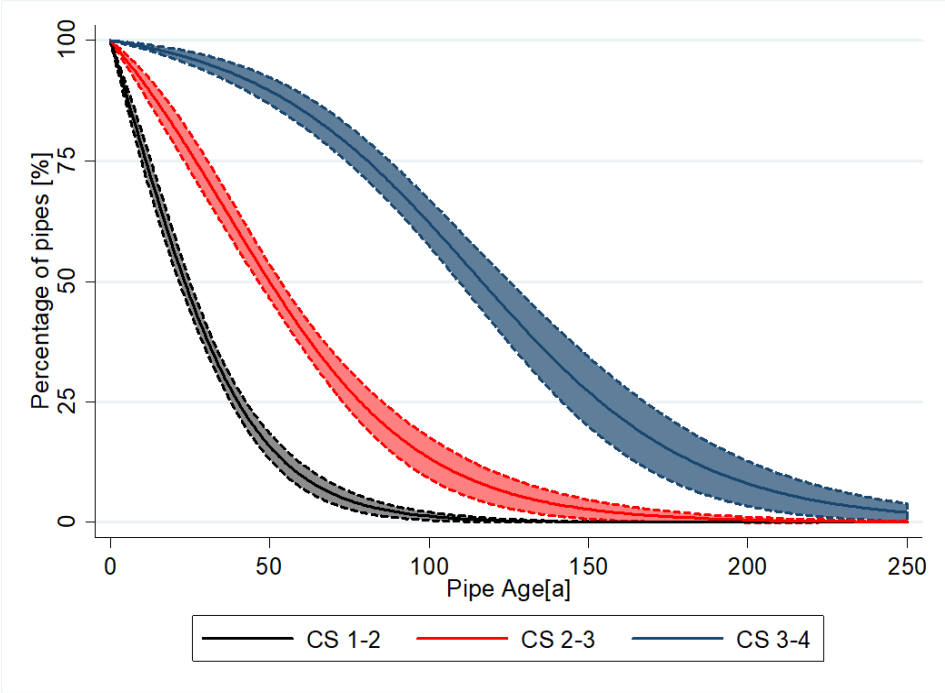
http://www.rapidview.com/interceptors.html

Possible Topics

- Influence of sewer condition assessment on deterioration models
  - Deterioration models are useful tools to identify pipes in critical condition and long-term investment planning.
  - For sewer systems they are based on Condition assessments mostly made using CCTV inspection
  - Because accuracy of visual inspection data is low the additional use of other types of information to investigate sewer system functioning is recommended (Dirksen et al. 2013). Classification in the range of 0-5 (representing good to poor condition) may vary between individual inspectors up to two steps.

Possible Topics

- Influence of sewer condition assessment on deterioration models
  - Question: What is the influence of this on our deteriora ecisions?



Source: Tscheikner-Gratl (2015)

Possible Topics

- Influence of data quality and measurement location on hydrodynamic sewer model calibration
- Decision support for sewer rehabilitation techniques
- Influence of sewer condition assessment on deterioration models

Possible Topics

- Influence of data quality and measurement location on hydrodynamic sewer model calibration
- Decision support for sewer rehabilitation techniques
- Influence of sewer condition assessment on deterioration models

- **Ideas from your side**